HYDRAULIC LABORATORY FOR THE GREATER ARMOUR INSTITUTE OF TECHNOLOGY

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1921

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A PROPOSED DESIGN FOR THE HYDRAULIC LABORATORY FOR THE GREATER ARMOUR INSTITUTE OF TECHNOLOGY

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

JUNE 2, 1921

APPROVED

Professor of Mechanical Engineering

Dean of Engineering Studies

Dean of Cultural Studies

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****** P R E F A C E ******

The purpose of assigning the subject, "A Proposed Design of a Hydraulic Laboratory for the Greater Armour Institute", was twofold:

First, it was to constitute a problem for two students, which would require a certain amount of research work, as well as to afford said students an opportunity to show some initiative in working out a problem, typical of the experiences to be encountered in the commercial world.

Briefly, it may be stated that the following proposed plan is entirely the students' conception of a laboratory altho frequent conferences were held with Professor L. Davies as to the size of equipment to be installed.

Second, altho it was not to be expected that this be a detailed design of a laboratory actually to be installed, still it was hoped that, in making a general layout of what constitutes a hydraulic laboratory, applicable to

the demands and conditions encountered, some data would be collected which would facilitate the work of determining the extent and allotment of the appropriation.

***** PRELIMINARY WORK *****

As stated in the preface, one of the primal objects of assigning this type of subject was to throw the students entirely on their own resources to see how they would attack the problem.

It is frankly confessed that at first the students were at a total loss as to how to proceed. Each had various vague notions about the apparatus to be installed, but when trying to arrange it, they were led deeper and deeper into new difficulties.

The first steps taken were the attempted collection of data of like installations. Letters were written to different universities asking for their plans and suggestions. The replies to these letters were of practically no help but seemed only to lead into deeper difficulties.

For instance: Several replies were to the effect that their laboratories were only excuses to get by. This type of reply, at first glance, seemed to be an easy way to side-step the ques-

tion and was discouraging. After due consideration, however, it was recognized that too much had been expected of them since initial plans, if any actually existed, soon become misplaced or lost. Furthermore, it would be necessary for the instructor of an institute to write a small volume at least to prepare a report on a laboratory installed in the typical hit or miss fashion in order that it be of any value for supplying the requested information. This certainly could not be expected of them.

The next step taken was the reading up on the few references on this subject which were available. Of these, the description of the laboratory of the Ohio State University, as given in the "Society for the Promotion of Engineering Education" was the most fruitful.

In the majority of cases it was found that too much unnecessary and expensive equipment was installed to show the most self-evident principles of hydraulics. For instance, at one university a considerable amount of space was taken up by ap-

paratus to show that the stream issuing from a jet or orifice fell in the form of a parabola. In order to accomplish this a very large tank was supplied with openings at different heighths. Sufficient head was produced to make the distance at which the water hit the ground ten to fifteen feet from the tank. A huge blackboard, divided into the Cartesian coordinates, was placed immediately behind this stream flow, the stream traced on the board, and from this the equation of the parabola was derived. This truly was a very ingenious scheme, but recourse to mathematics was still necessary so it is open to criticism since one can readily arrive at the same conclusions with the application of a few fundamental principles of physics and practically the same amount of mathematics.

This was only one of the many like conditions found. This type of equipment was eliminated because it was felt that only such apparatus warranted consideration as would bring out the fundamental hydraulic principles that are

commercialized, since classroom demonstrations are just as convincing for this particular kind of instruction.

The natural topography of the country surrounding Cornell University is so favorable that their hydraulic laboratory is perhaps unequalled for work with impulse wheels and reaction turbines. The adoption of any of their plans was impossible since they are not applicable to conditions here. It would be impractical to pump the large quantities of water to such a height as to duplicate Cornell's natural available supply of water at high head.

Professor Davies, after personally investigating conditions at the University of Wisconsin, made many practical suggestions. The University of Wisconsin is also favored by natural topography. They have a huge reservoir at the top of a hill giving a head of about eighty feet. The laboratory itself is situated just above the datum line of a lake. This fact, together with the arrangement in their laboratory,

gives them several levels thus greatly facilitating the handling of water.

One of the main factors of the problem consisted of a means for measuring large volumes of water, in order to calibrate the comparatively large weirs. This was easily solved at the University of Wisconsin by noting the quantity of water supplied to the laboratory. This was accomplished by gauging the different levels of the water in the reservoir before and after the interval of time elapsing during the test. The reservoir was cylindrical in cross-section, and, by noting the level drop, the quantity supplied could be directly computed in cubic feet. This is a typical accepted means of gauging water by volumetric measurement. This system can only be used, however, when the natural environment is favorable. The other alternative was that adopted by the Ohio State University, where the sump was made a means of measuring volume. In this instance the sump was divided into quadrants, intercon-

nected by submerged gates of the Portcullis type. A convenient pit or observation well, as it was called, was constructed along side of the sump in which gauge glasses and hook gauges were located to provide a means of noting the heights of water in each pit. Then, knowing the cross-section of the quadron, and the rise and level of water, the quantity supplied could be determined.

This latter plan could not be directly applied since it necessitates the discharging into the sewer of a large quantity of water, thus involving a needless waste of water and expense as all the water must be purchased at the new site.

****** THE PROPOSED PLAN ******

The following plan was adopted after correlating all the material accessible on existing laboratories, and the elimination of the unsuited or unnecessary parts in an endeavor to make the new laboratory as suited as possible to conditions found at the new site.

One of the first difficulties which presented themselves was the condition of the subsoil at the new site. A strata of limestone is found at about eight feet below datum, actually outcropping in some places in the locality. This fact has to be taken into consideration in planning the building since, if a basement were excavated, it would be necessary to blast rock in order to make the sump. This then would cause drainage trouble as the sewage system of the locality is near the datum, due also to the rocky subsoil.

All water to be used at the new institute

must be purchased. This necessitates the construction of a small artificial lake to provide a source of supply for the fire protection laboratory and hydraulic laboratory, as well as a spray pond to be used in connection with the power plant.

Professor Gebhardt suggested that the spray pond be an acre in area. Great depth is unnecessary for spray pond purposes, since it is only the evaporating surface that is effective. By making the pond deep enough, however, it would function as a reservoir for the laboratories as well. The limiting value for depth is eight feet due to the rock strata. Since the exhaust steam from the power plant would be used for heating purposes in the winter, the spray pond being deprived of the warm return water would freeze up. In this region, ice forms to a layer of about eighteen inches thick. Thus, allowing two feet for ice formation on an eight foot depth, a capacity due to the remaining six feet would still be

available in the winter. This would be about 50,000 cu.ft., which would be sufficient for all reasonable demands that could be placed upon it.

It was decided then to have the main floor of the laboratory well above the datum of this pond in order that the weight and volumetric tanks may empty into it.

****** THE BUILDING ******

In order to avoid, as much as possible, the duplication of apparatus, it was decided to place the hydraulic and the steam laboratories in the same building adjacent to each other. Then the water necessary for the condensers could be taken directly from the sump. Another favorable factor is the combining of a large steam turbine with a centrifugal pump, thus using to advantage this large steam unit for pumping water which otherwise would have been used

only for a steam experiment.

Therefore, it was decided that the two laboratories jointly occupy a building 180 feet long by 100 feet wide built with the first floor one foot above datum. The second floor is to be in the form of a balcony 30 feet wide on three sides and ten feet wide on the remaining side.

All apparatus pertaining to student experimental work is located on the balcony reserving almost the entire main floor for research and commercial work. One portion of the main floor is to be devoted to an office, 24 feet by 20 feet in which cabinets for filing away log sheets and experiments are to be built. Cabinets should also be placed conveniently in the main laboratory for the safekeeping of instruments, small accessories for the laboratory and tools, pipe fittings, etc.

To facilitate the work of reconnecting temporary apparatus, as well as for experimental work, it is recommended that work benches, fitted with pipe and machinist's vices, be part

of the regular laboratory equipment together with a complete set of pipe cutting and threading tools to take pipe up to at least two inches.

****** THE APPARATUS ******

The apparatus necessary for a hydraulic laboratory divides itself into three general groups which are: First, the apparatus for measuring the flow of water, second, the pumps required for lifting water, causing flow, and maintaining head, and third, the apparatus for utilizing hydraulic energy.

These three main divisions subdivide themselves into:

I. - APPARATUS FOR MEASURING FLOW.

A - Large Weir and Flume measurements.

B - Venturi and Water Meters.

C - Friction in Pipes.

D - Flow thru Tubes, Nozzles & Orifices.

II. - PUMPS FOR LIFTING WATER.

A - Centrifugal Pumps.

1. - 1,000 G.P.M. Pump.

2. - 250 " "

3. - 50 " "

B - Steam Reciprocating Pumps.

C - Rams.

III. - APPARATUS FOR UTILIZING HYDRAULIC ENERGY.

A - Pelton Wheels.

B - Hydraulic Turbines.

***** APPARATUS FOR MEASURING FLOW *****

A - LARGE WEIR AND FLUME MEASUREMENTS.

The large weir located on the second floor is 16 feet long, ten feet wide and 4 feet high. The weir is to be used with the full 10 feet breadth when operating without end contractions, and to have a breadth of 4 feet when using end contractions. The weir is to be constructed of sheet iron and raised about two feet off the floor. The weir can be calibrated by measuring the spill-way water in two large volumetric tanks located on the floor below.

The volumetric tanks, which are 20 x 25 x 8 feet, are capable of handling 3,000 gallons per minute, when dumping every ten minutes. The tanks empty into the sump which is a long, narrow, open rectangular pit running the remaining length of the laboratory. This sump can be quite narrow and still have a practically unlimited capacity by virtue of its being con-

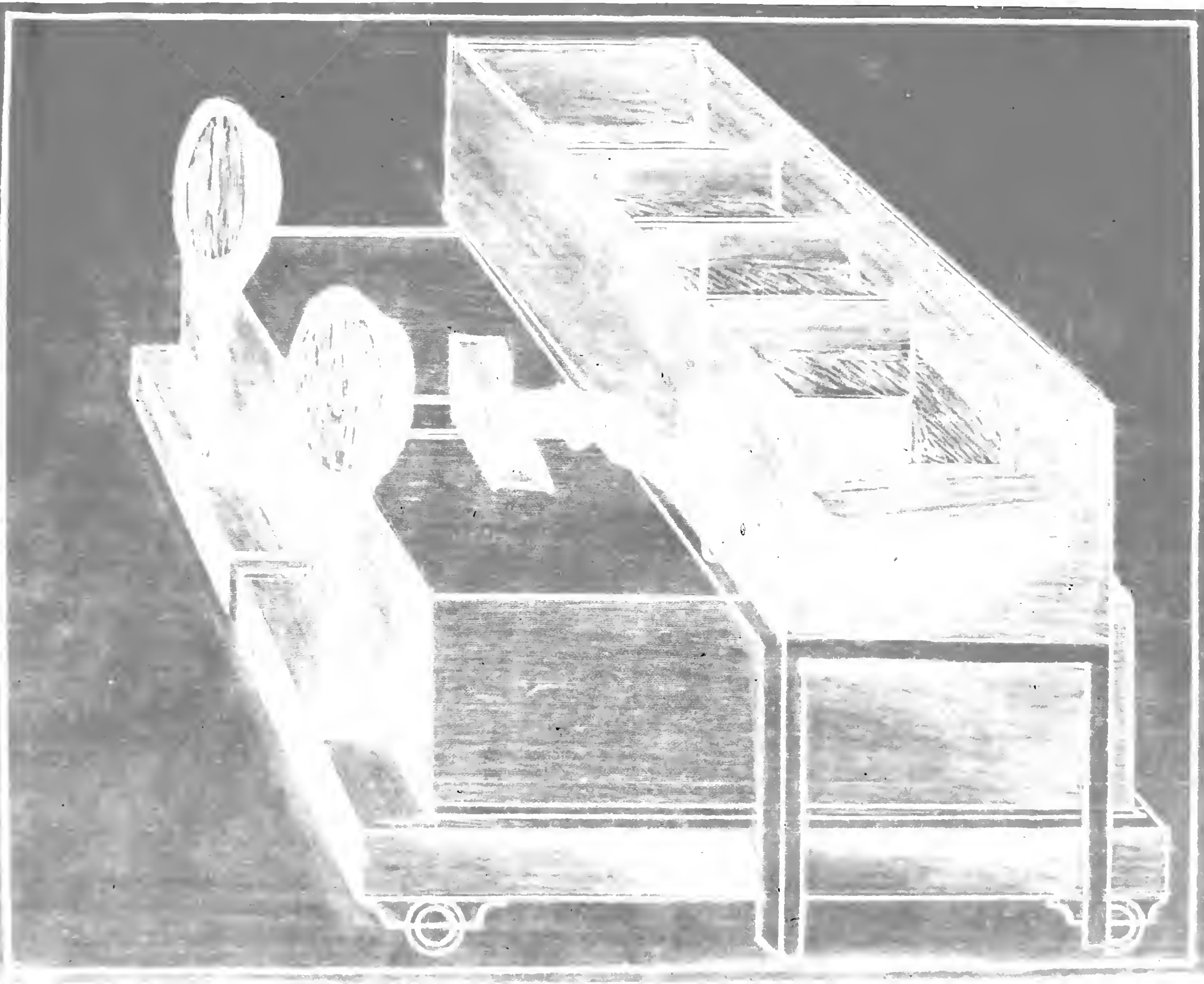
nected to the spray pond by a 4 x 4 foot tunnel.

By operating two gates the water, after flowing over the weir, can be made to flow into the flume below. This flume is to be constructed of reinforced concrete, four feet square in cross section and over 100 feet in length. (See layout sheet.) The terminal of the flume is to be 4 feet by 10 feet in cross section in order to provide a means of using large weirs or to facilitate any other experimental work other than that calculated for the flume itself. Suitable means are to be provided at intervals along the flume for the purpose of dividing off sections, placing in of obstructions, or for mounting weir plates.

The flume is to be used primarily for determining the coefficient of flow in a channel. It may also be used for determining the resistances of screens and other obstructions as well as for experimental work with submerged weirs.

SMALL WEIRS.

The smaller weirs are installed exclusively for student experimental work. One of these weirs has a rectangular notch ten inches wide. The box itself is rectangular in shape, lined with zinc and is 6' x 2'-8" x 1'-6". The baffling is accomplished by inserting perferated boards to insure a free flow over the notch, without ripples or other disturbances. The discharge over the notch is caught by a sheet metal apron which conducts the water to two weight tanks. These tanks are rectangular in shape, constructed of 3/32 inch steel plate and are 3' x 4' x 3'. The water drains from the tank thru a 3 inch valve at the bottom. A flexible connection is made by attaching a short piece of rubber hose from this valve to the drain pipe. These tanks are mounted on platform scales of the "Kron" automatic springless type. This type of scale is advantageous since the weight can be read off directly with even greater accuracy than with the older form



of platform scale.

The other weir is identical with the one just described with the exception of the notch which is in the form of a "V" instead of a rectangle.

B - VENTURI AND WATER METERS.

This apparatus consists of a Venturi section placed in a $1\frac{1}{2}$" pipe line. The water discharged from the Venturi flows into the weight tanks which are the same size as those used in connection with the weirs. Venturi meters are also placed in the discharge lines of all centrifugal pumps installed in the laboratory.

Several water meters are also placed in this line and are to be calibrated by the use of these same weight tanks.

C - FRICTION IN PIPES.

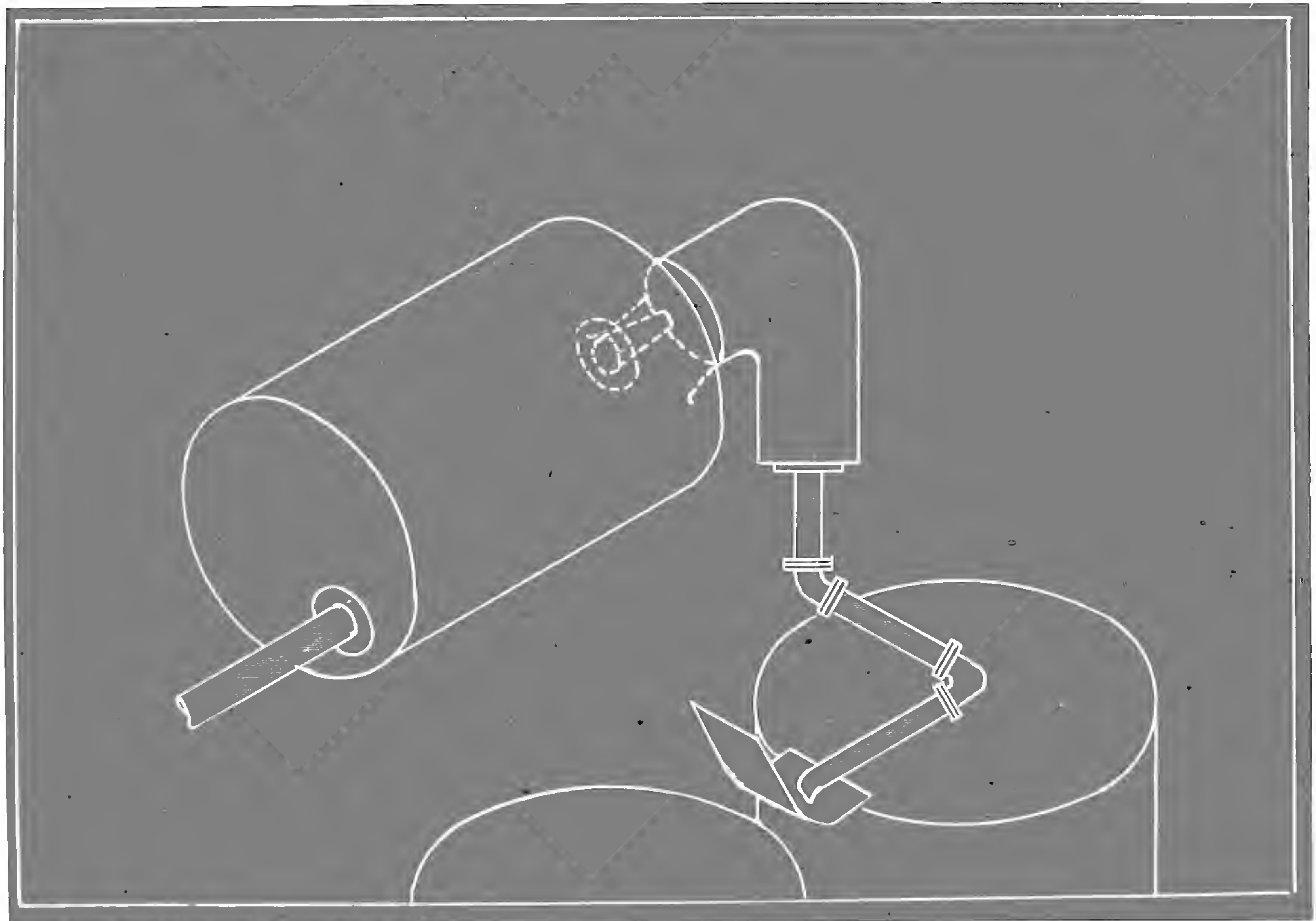
The equipment for this experiment consists of two pipe lines. One, a three inch pipe

line taken from the 250 gallons per minute pump, as well as a one and one-half inch pipe line taken from the 50 gallon per minute pump. These pipe lines are located side by side under the balcony and run completely around the laboratory. This arrangement permits the combined discharge of all three pumps to be supplied to the larger weir. The pipe lines contain five elbows, one tee, as well as several valves in each line. A straight line of pipe 160 feet long is available for determining the friction of straight line flow. Manometer openings are placed on each side of all fittings.

D - FLOW THRU TUBES, NOZZLES AND ORIFICES.

Due to the increasing demand for equipment to make commercial tests, it was found necessary to install two sets of apparatus, one for commercial work and a smaller one for student experiments.

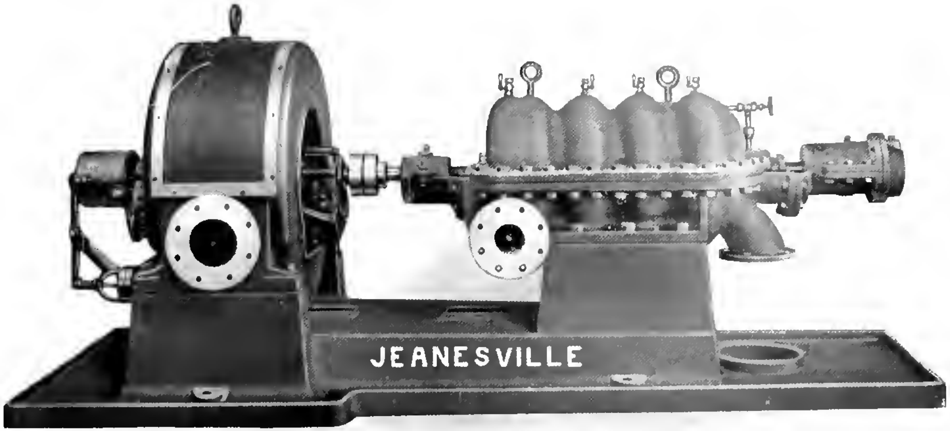
The larger consists of a tank three feet in diameter and four feet long. The water is



supplied by the centrifugal pump capable of producing a head of 300 feet. The nozzles, orifices, or tubes are to be fastered to the flange on the opposite side. The calibration is made by weighing the water. Two tanks eight feet high and four feet in diameter placed on Kron platform scales are part of the large equipment. The tanks used for the small set are rectangular in shape, four feet square by three feet deep and also mounted on Kron scales.

DOUBLE SUCTION TURBINE PUMPS

JEANESVILLE BOILER FEED PATTERN



****** PUMPS FOR LIFTING WATER ******

A - CENTRIFUGAL PUMPS.

1. - 1,000 G.P.M. Pump.

The large pump will supply 1,000 gallons per minute at a head of 450 feet. This pump will be directly connected to a large steam turbine.

Two types of pumps were considered. One a six inch four stage Volute Centrifugal Pump, which requires 167 brake horse power running at a speed of 1750 R.P.M. with an efficiency of 70%; the other, a six inch three stage Double Suction Pump requiring 165 brake horse power at a speed of 1750 R.P.M. with an efficiency of 71%.

The six inch four stage Volute Pump was chosen because it was best adapted to conditions under which it will operate and on account of its simplicity of design.

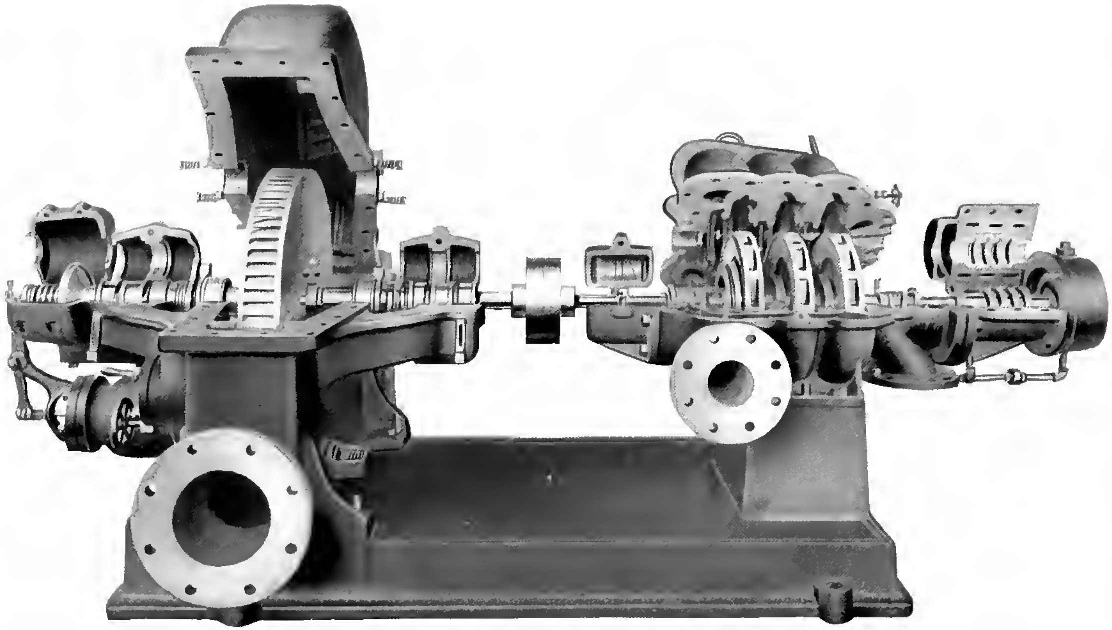
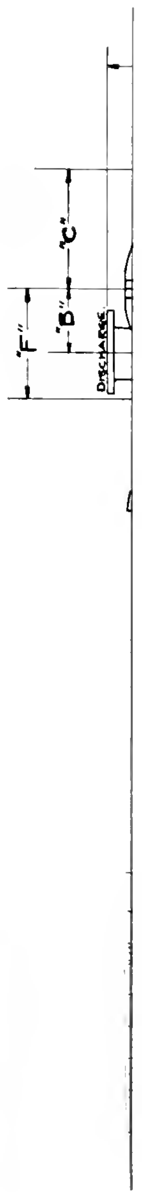


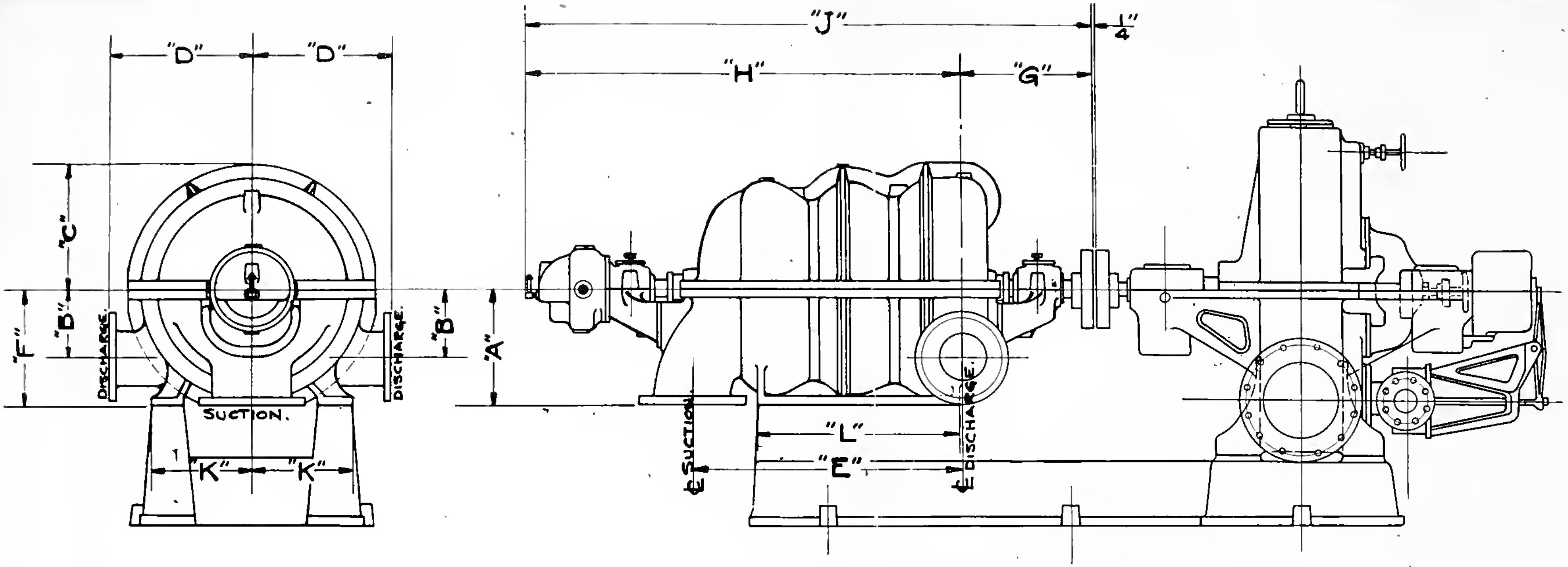
Fig. 1534.

JEANESVILLE CENTRIFUGAL PUMP.

THREE-STAGE TURBINE TYPE, SHOWING ACCESSIBILITY OF SPLIT CASING DESIGN

WORTHINGTON PUMP AND MACHINERY CORPORATION


"F"
"B"
"C"
DISCHARGE



DIMENSIONS OF DOUBLE SUCTION TURBINE PUMP

Size of Pump	Discharge Dia.	Suction Dia.	A	B	C	D	E			F	G	H			J			K	L		
							2 St.	3 St.	4 St.			2 St.	3 St.	4 St.	2 St.	3 St.	4 St.		2 St.	3 St.	4 St.
4	4	5	$11\frac{3}{4}$	$7\frac{1}{4}$	$10\frac{1}{2}$	$12\frac{3}{4}$	$17\frac{13}{16}$	$21\frac{15}{16}$	$32\frac{1}{16}$	$11\frac{3}{4}$	$20\frac{1}{2}$	$39\frac{3}{8}$	$46\frac{5}{8}$	$53\frac{7}{8}$	$59\frac{7}{8}$	$67\frac{1}{8}$	$74\frac{3}{8}$	10	$9\frac{13}{16}$	$16\frac{15}{16}$	$24\frac{1}{16}$
5	5	6	14	$8\frac{1}{2}$	$12\frac{1}{4}$	$15\frac{1}{2}$	$22\frac{9}{16}$	$31\frac{5}{16}$	$40\frac{1}{16}$	14	$20\frac{1}{4}$	$42\frac{3}{4}$	$51\frac{1}{2}$	$60\frac{1}{4}$	63	$71\frac{3}{4}$	$80\frac{1}{2}$	12	$12\frac{9}{16}$	$21\frac{5}{16}$	$30\frac{1}{16}$
6	6	8	16	9	$14\frac{3}{4}$	20	$23\frac{7}{8}$	$33\frac{5}{8}$	$43\frac{3}{8}$	16	$22\frac{1}{2}$	$49\frac{1}{4}$	59	$68\frac{3}{4}$	$71\frac{3}{4}$	$81\frac{1}{2}$	$91\frac{1}{4}$	$13\frac{1}{2}$	$13\frac{3}{8}$	$23\frac{1}{8}$	$32\frac{7}{8}$
8	8	10	19	$10\frac{1}{4}$	$17\frac{1}{2}$	$23\frac{1}{2}$	29	$40\frac{1}{2}$	....	19	$22\frac{7}{8}$	$54\frac{5}{8}$	$66\frac{1}{8}$	....	$77\frac{1}{2}$	89	....	$15\frac{3}{4}$	$19\frac{3}{4}$	$31\frac{1}{4}$	....
10	10	12	$24\frac{1}{2}$	$14\frac{1}{2}$	$22\frac{3}{4}$	30	$34\frac{1}{2}$	49	....	$24\frac{1}{2}$	29	$59\frac{3}{4}$	$74\frac{1}{4}$	....	$88\frac{3}{4}$	$103\frac{1}{4}$	....	$20\frac{1}{2}$	$20\frac{1}{4}$	$34\frac{3}{4}$	....

Diameter of Opening	Drilling for Suction Flange				Drilling for Discharge Flange			
	Dia. of Flange	No. of Bolts	Size of Bolt	Dia. Bolt Circle	Dia. of Flange	No. of Bolts	Size of Bolt	Dia. Bolt Circle
4	....	....	....	....	10	8	$\frac{3}{4}$	$7\frac{7}{8}$
5	10	8	$\frac{3}{4}$	$8\frac{1}{2}$	11	8	$\frac{3}{4}$	$9\frac{1}{4}$
6	11	8	$\frac{3}{4}$	$9\frac{1}{2}$	$12\frac{1}{2}$	12	$\frac{3}{4}$	$10\frac{5}{8}$
8	$13\frac{1}{2}$	8	$\frac{3}{4}$	$11\frac{3}{4}$	15	12	$\frac{7}{8}$	13
10	16	12	$\frac{7}{8}$	$14\frac{1}{4}$	$17\frac{1}{2}$	16	1	$15\frac{1}{4}$
12	19	12	$\frac{7}{8}$	17	....	....	....	....

****** SPECIFICATIONS ******

CASING.

The casing will be of the double volute type, split in a horizontal plane, made of the best material, with suction and discharge openings integral with the lower half and on opposite sides. This design permits a quick and easy access to the interior of the pump for inspection and repairs, without distrubing the pipe connections or allignment of the pump. Both halves of the casing will be fitted with flanges, carefully faced, drilled and bolted together; the joint made with an especially prepared gasket. The return chamber leading the water from stage to stage is case as part of the casting itself.

IMPELLERS.

The impellers will be of the single suction enclosed type. They are cast in one piece and are machined and polished on the outside, the ports chipped and filed smooth. They will be

placed back to back in order to hydraulically balance the end thrust. The water is discharged from the first impeller to the suction of the second thru a volute chamber. The hubs of each impeller revolve in renewable cast bronze wearing rings to take up the wear and prevent leakage into the suction and the formation of eddy currents. The impellers are secured to the shaft with feather keys, and the revolving parts are in accurate rotative balance.

SHAFT.

The shaft will be of high quality carbon steel perfectly straight, true and round, and will be of ample size to easily transmit the maximum power required at full speed and capacity. It will be protected by bronze sleeves wherever it comes in contact with the fluid handled, and thru the stuffing boxes on the pump casing. These sleeves can be easily removed. The shaft bushings screwed against the impeller hub act as lock nuts.

BEARINGS.

There will be one horizontally split dust proof bearing on each side of the pump, of ample size to properly distribute the load and insure free running qualities. Both bearings will consist of removable shells of special bearing metal bored and scraped to fit the shaft. The bearings on both ends will be lubricated by the ring oiling method, and have large oil pockets to insure thoro cooling of the oil. A light thrust bearing will be embodied in the outboard bearing shell to take care of any slight unbalanced difference of end thrust due to possible fluctuations in capacity.

STUFFING BOXES.

The stuffing boxes will be provided with water seals, consisting of a lantern gland in the box connected to the pressure water on the discharge side of the pump. This method of sealing effectually prevents suction air leaks , and is essential to the successful operation of

the pump when high suction lifts are encountered.

COUPLING.

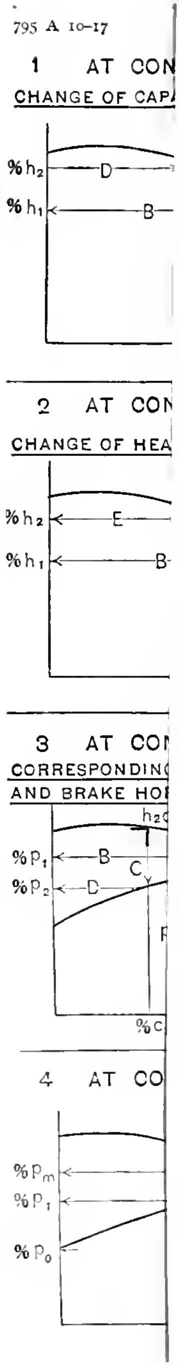
A flexible coupling will connect the pump shaft to the prime mover. It will be of the pin and rubber buffer type, especially designed to afford maximum flexibility.

BEDPLATE.

The bedplate upon which the pump is mounted will be designed of ample cross section to give a rigid foundation.

PERFORMANCE.

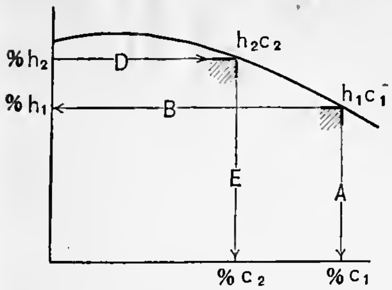
The following sheet shows the characteristic curves for a Worthington and American Well Works pump.



795 A 10-17
1 AT CON
CHANGE OF CAPA
%h2
D
%h1
B
2 AT CON
CHANGE OF HEA
%h2
E
%h1
B
3 AT CON
CORRESPONDING
AND BRAKE HOR
h2
%P1
B
C
%P2
D
F
%C
4 AT CO
%Pm
%P1
%P0

1 AT CONSTANT SPEED TO DETERMINE

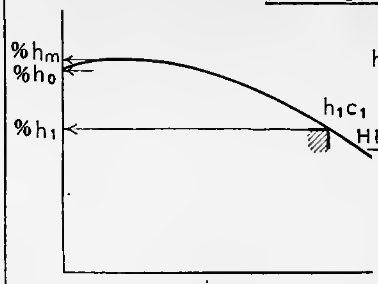
CHANGE OF CAPACITY CORRESPONDING TO CHANGE OF HEAD



A-read $\%c_1$ off curve
B-read $\%h_1$ off curve
C-calculate $\%h_2 = \frac{h_2}{h_1}\ \%h_1$
D-follow $\%h_2$ to intersection with same head-capacity curve as h_1, c_1
E-read $\%c_2$ off curve
F-calculate $c_2 = \frac{\%c_2}{\%c_1}\ c_1$

5 AT CONSTANT SPEED TO DETERMINE

MAXIMUM HEAD DEVELOPED BY PUMP



$$h_{max} = \frac{\%h_m}{\%h_1}\ h_1$$

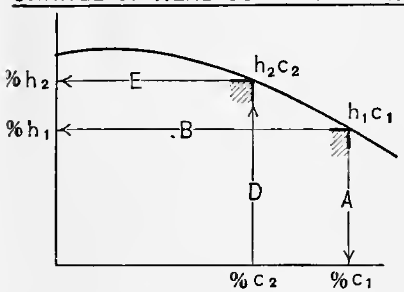
HEAD DEVELOPED AT SHUT-OFF

(ZERO CAPACITY)

$$h_{\text{at shut off}} = \frac{\%h_o}{\%h_1}\ h_1$$

2 AT CONSTANT SPEED TO DETERMINE

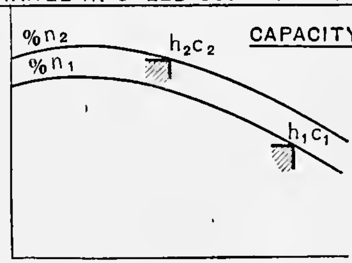
CHANGE OF HEAD CORRESPONDING TO CHANGE OF CAPACITY



A-read $\%c_1$ off curve
B-read $\%h_1$ off curve
C-calculate $\%c_2 = \frac{c_2}{c_1}\ \%c_1$
D-follow $\%c_2$ to intersection with same head-capacity curve as h_1, c_1
E-read $\%h_2$ off curve
F-calculate $h_2 = \frac{\%h_2}{\%h_1}\ h_1$

6 AT VARIABLE SPEED TO DETERMINE

CHANGE IN SPEED CORRESPONDING TO CHANGE IN HEAD-CAPACITY CONDITIONS

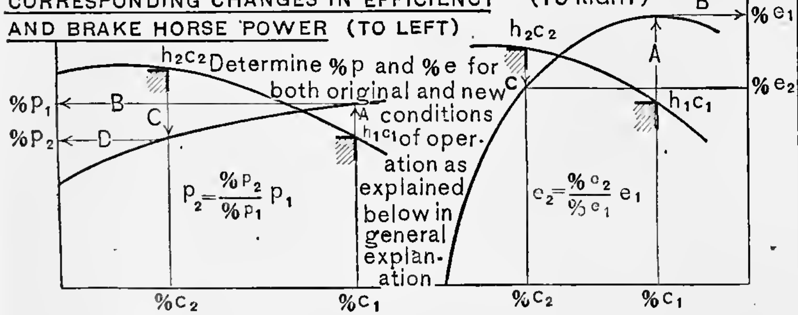


Mark both original and new conditions of operation on curve
Determine $\%n_1$ and $\%n_2$ from variable speed head-capacity curves

$$n_2 = \frac{\%n_2}{\%n_1}\ n_1$$

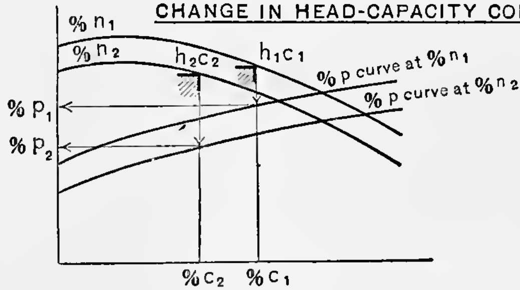
3 AT CONSTANT SPEED TO DETERMINE

CORRESPONDING CHANGES IN EFFICIENCY (TO RIGHT) AND BRAKE HORSE POWER (TO LEFT)



7 AT VARIABLE SPEED TO DETERMINE

CHANGE IN BRAKE HORSEPOWER CORRESPONDING TO CHANGE IN HEAD-CAPACITY CONDITIONS

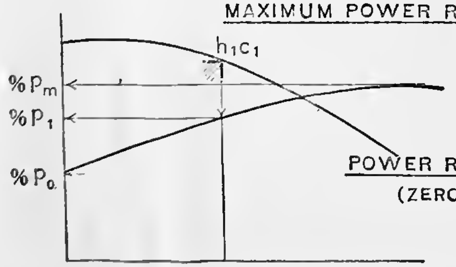


Determine $\%p_1$ and $\%p_2$ as indicated

$$p_2 = \frac{\%p_2}{\%p_1}\ p_1$$

4 AT CONSTANT SPEED TO DETERMINE

MAXIMUM POWER REQUIRED BY PUMP



$$p_{max} = \frac{\%p_m}{\%p_1}\ p_1$$

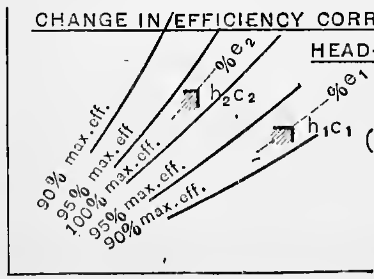
POWER REQUIRED AT SHUT-OFF

(ZERO CAPACITY)

$$p_{\text{at shut off}} = \frac{\%p_o}{\%p_1}\ p_1$$

8 AT VARIABLE SPEED TO DETERMINE

CHANGE IN EFFICIENCY CORRESPONDING TO CHANGE IN HEAD-CAPACITY CONDITIONS



Determine $\%e_1$ and $\%e_2$ (interpolating if necessary between lines of constant efficiency)

$$e_2 = \frac{\%e_2}{\%e_1}\ e_1$$

EXPLANATION OF CHARACTERISTIC CURVES.

HEAD IN PERCENT OF HEAD AT MAXIMUM EFFICIENCY POINT.-
B.H.P. IN PERCENT OF B.H.P. AT MAXIMUM EFFICIENCY POINT.-

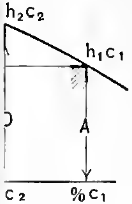
0 20 40 60 80 100 120 140 160 180 200

curve as h_1, c_1
E - read $\% c_2$ off curve
F - calculate $c_2 = \frac{\% c_2}{\% c_1} c_1$

$h_{\text{at shut off}} = \frac{\% h_0}{\% h_1} h_1$

NT SPEED TO DETERMINE

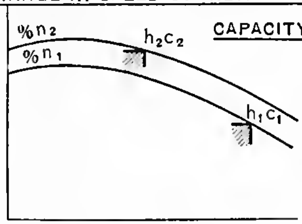
RRESPONDING TO CHANGE OF CAPACITY



A-read $\% c_1$ off curve
B-read $\% h_1$ off curve
C-calculate $\% c_2 = \frac{c_2}{c_1} \% c_1$
D-follow $\% c_2$ to intersection with same head-capacity curve as h_1, c_1
E - read $\% h_2$ off curve
F - calculate $h_2 = \frac{\% h_2}{\% h_1} h_1$

6 AT VARIABLE SPEED TO DETERMINE

CHANGE IN SPEED CORRESPONDING TO CHANGE IN HEAD-CAPACITY CONDITIONS



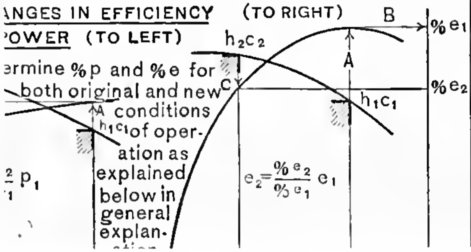
Mark both original and new conditions of operation on curve
Determine $\% n_1$ and $\% n_2$ from variable speed head-capacity curves

$n_2 = \frac{\% n_2}{\% n_1} n_1$

NT SPEED TO DETERMINE

NGES IN EFFICIENCY (TO RIGHT)

OWER (TO LEFT)



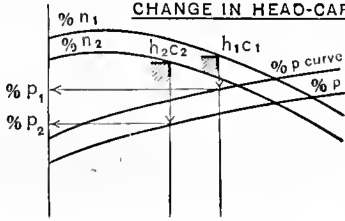
ermine %p and %e for both original and new conditions of operation as explained below in general explan-

$e_2 = \frac{\% e_2}{\% e_1} e_1$

$\frac{2}{1} p_1$

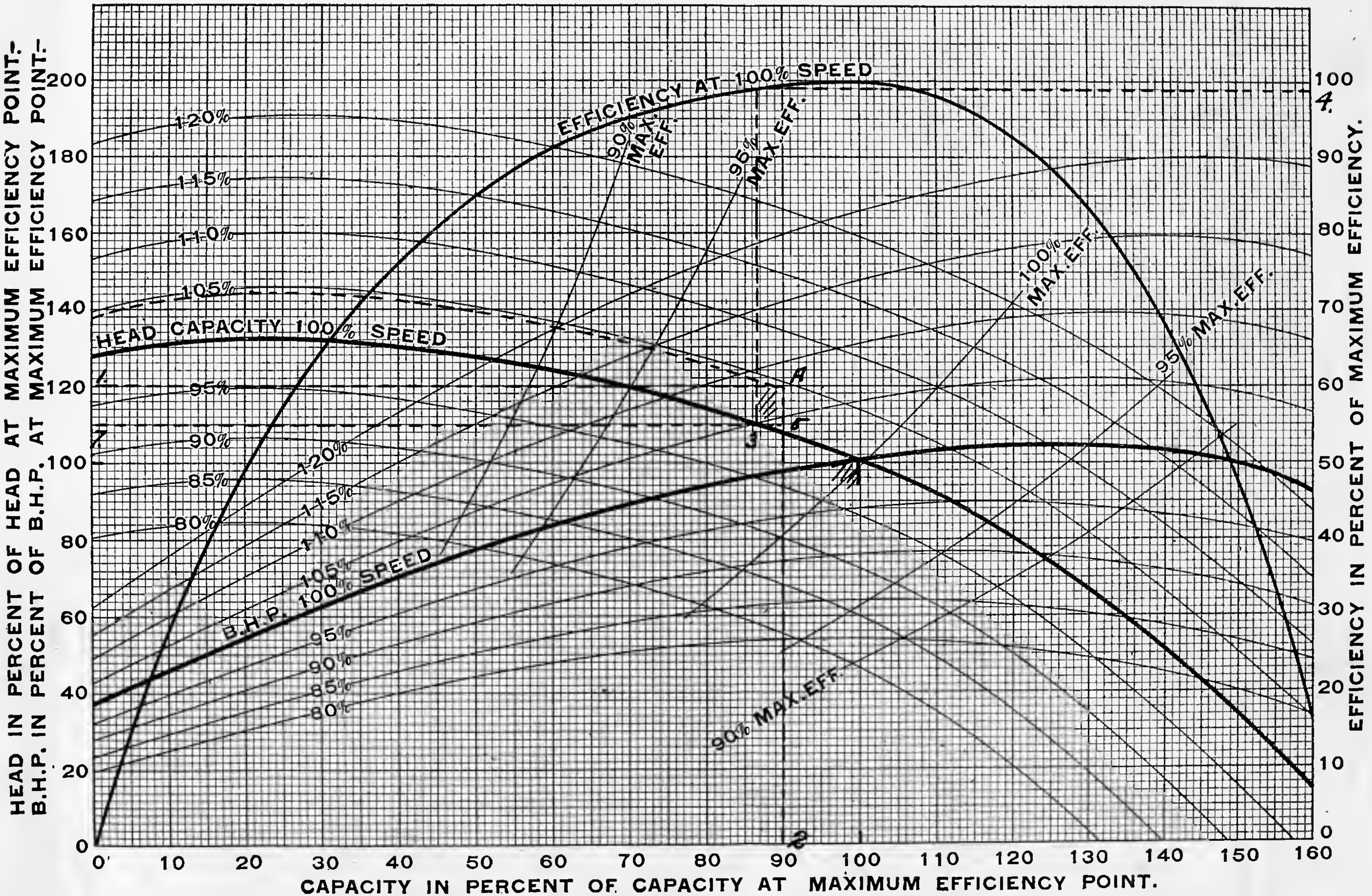
7 AT VARIABLE SPEED TO DETERMINE

CHANGE IN BRAKE HORSEPOWER CORRESPONDING TO CHANGE IN HEAD-CAPACITY CONDITIONS



Determine $\% p_1$ and $\% p_2$ as indicated

$p_2 = \frac{\% p_2}{\% p_1} p_1$



CHARACTERISTIC CURVE

INTERPOLATION OF CURVES.

The characteristic curves are based on average test results of a given type of impeller and are applicable to any impeller of that type with the reservation that being an average, they cannot be expected to be guaranteed throughout their entire range for any particular case.

These curves indicate the changing relations between head, capacity, speed, efficiency and brake horsepower corresponding to variations of one or more of these factors, and are drawn up for the operating range within which changes can be predicted with a satisfactory degree of accuracy.

In order to make these curves more conveniently applicable to a particular case, the ordinates and abscissae are given in terms of percentages of head, capacity, brake horsepower, and efficiency for the operating point at which the pump will be most efficient. After this

point has been determined from a previous series of tests, any other point of operation can be closely determined by simple proportion as explained further on in this discussion.

In discussing the use of these curves, the following notation will be used: -

h = head
c = capacity
e = efficiency
p = brake horsepower
n = speed

%h = head in percent of head at max. efficiency point - read at left hand margin of curve.

%c = capacity in percent of capacity at max. eff.point - read at bottom margin of curve.

%e = efficiency in percent of efficiencyat max. eff.point - read at right hand margin of curve.

%p = brake horsepower in percent of BHP at max. eff. point - read at left hand margin of curve.

%n = speed in percent of speed at original condition of operation - read on head - capacity and BHP - capacity curves.

Subscript 1 = original condition of operation.

Subscript 2 = new condition of operation.

It is first necessary to mark the position of the original (or normal) condition of operation h_1, c_1, e_1, as shown by in order to have a starting point from which to base the calculations for any other condition of operation. This point is to be indicated on the head capacity curve drawn up for 100% or normal operating speed.

In making calculations for new points of operation, after this point has been indicated on the curve, the corresponding percentages as $\%h_1$, $\%c_1$, $\%e_1$, and $\%p_1$, are next to be read off at the proper margin, and the procedure will then be as indicated in the Examples given above the general rule for determining any new factor being shown by the relation.

$$\frac{h_2}{h_1} = \frac{\%h_2}{\%h_1}$$

For any operating point the required brake horsepower will be given as $\%p$ at the intersection of the $\%c$ abscissa with the horsepower curve

drawn up for the speed at which the head and capacity are to be obtained.

For any operating point at normal or 100% speed the corresponding efficiency will be given at the intersection of the %c abscissa with the efficiency curve drawn up at 100% speed. For any other speed, the calculation is as follows:

Given 100% condition, as marked on the curve, required to operate a 90% capacity and 120% head or 900 gallons per minute and 264 foot head indicated at point A. At point 1 read 120% x 220' equals required head. At point 2, read 90% x 1000 G.P.M. equals required capacity. From A run a line parallel to constant efficiency line until it intersects the Head - capacity - 100% speed line. Then read vertically up to effbiency curve, then to point 4 obtaining 98% of 70% efficiency for new condition . New speed will be 104 plus percent of 1750 as shown by head capacity curve. New brake

horsepower for speed of 104 + % x 1750 will be point 5. Read horizontally to 110% of 100% brake horsepower or 110% x 83 brake horsepower, shown at point 7.

2. - 250 G.P.M.

The medium sized pump is to supply 250 gallons per minute at a head of 300 feet.

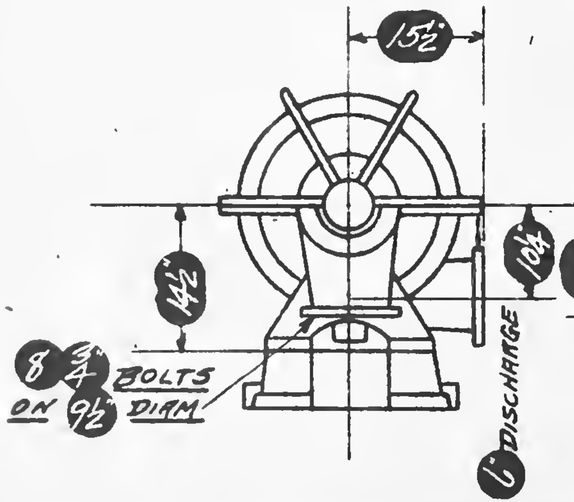
Two types of pumps were considered. One, a three inch Two Stage Volute Centrifugal Pump which requires 40 B.H.P. when running at a speed of 1750 R.P.M. with an efficiency of 51%; the other, a Four inch Two Stage Double Suction Volute Pump requiring 45 B.H.P. at 2300 R.P.M. with an efficiency of 55%.

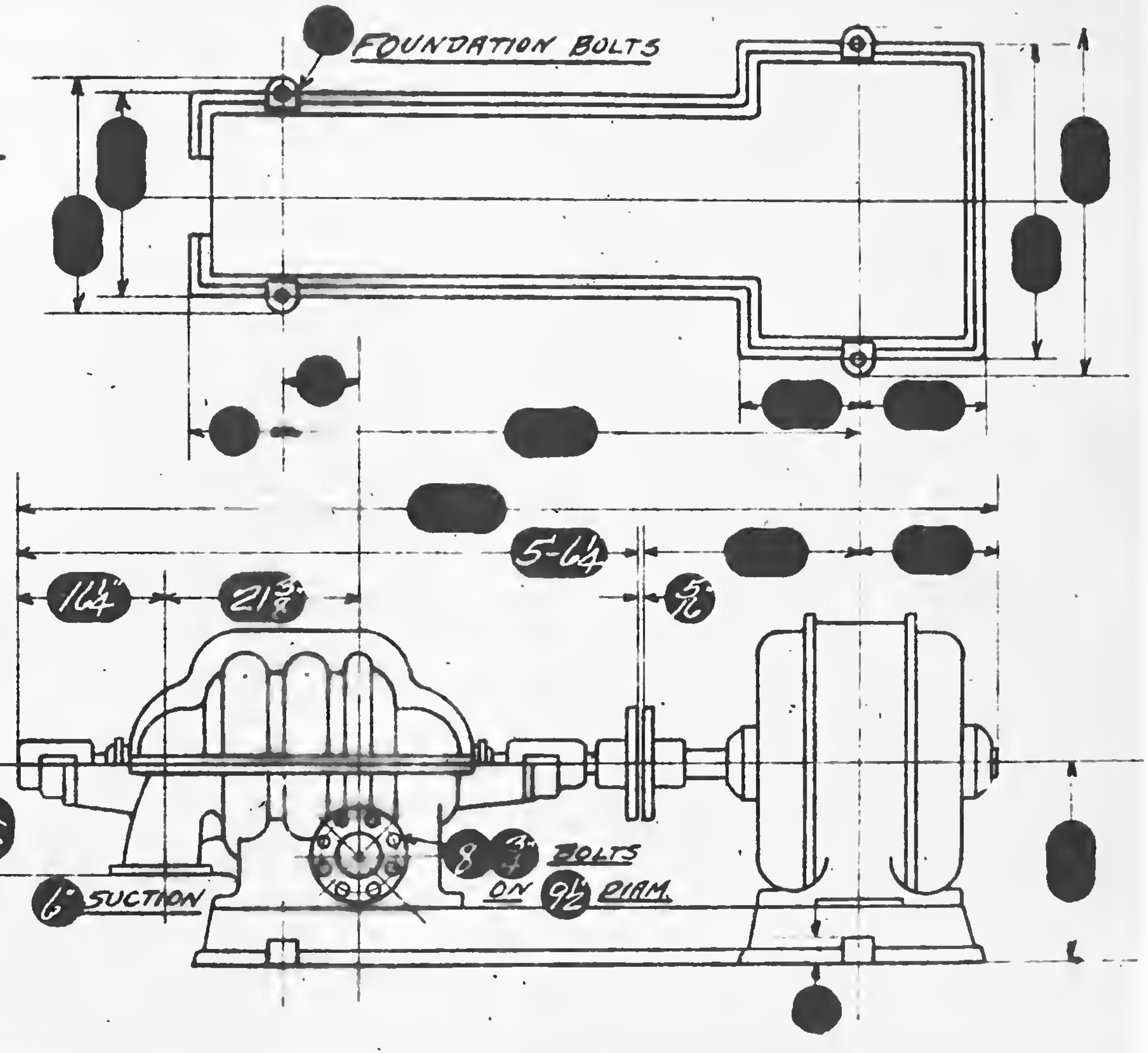
The Three inch Two Stage Volute Pump was chosen because of its simplicity and on account of its being hydraulically balanced, and also because of cheapness of construction.

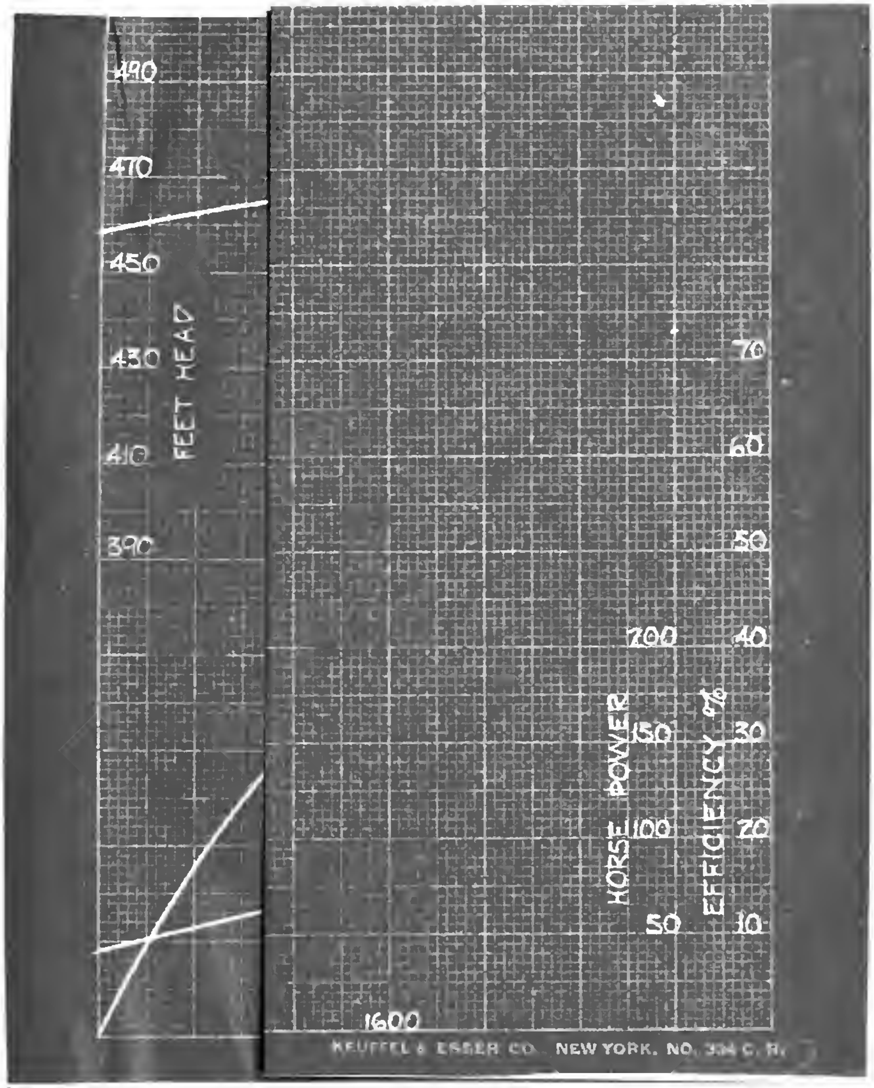
TYPE KT3MB 3 STAGE

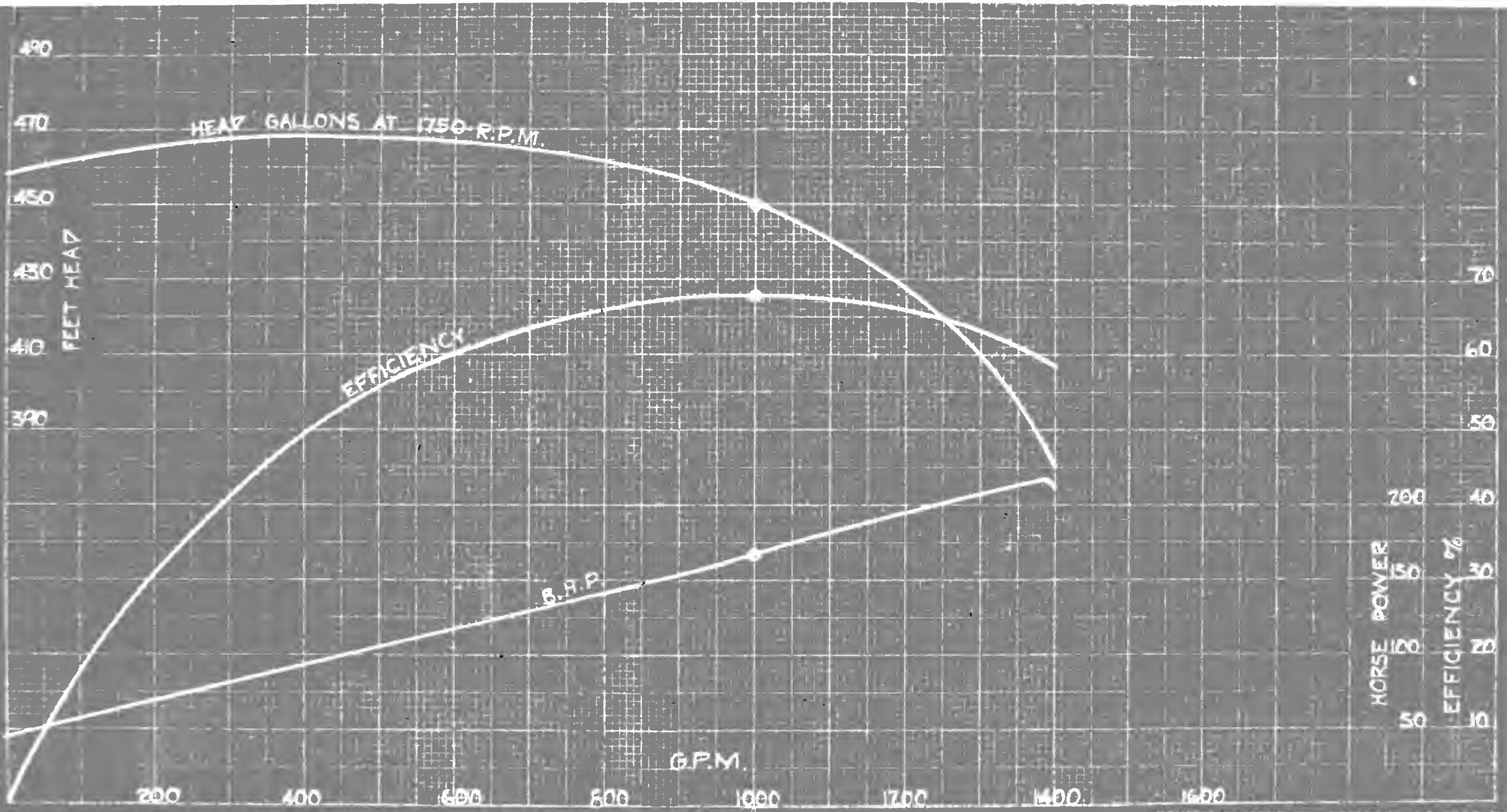
"AMERICAN" CENTRIFUGAL PUMP

THE AMERICAN WELL WORKS,
AURORA, ILL.

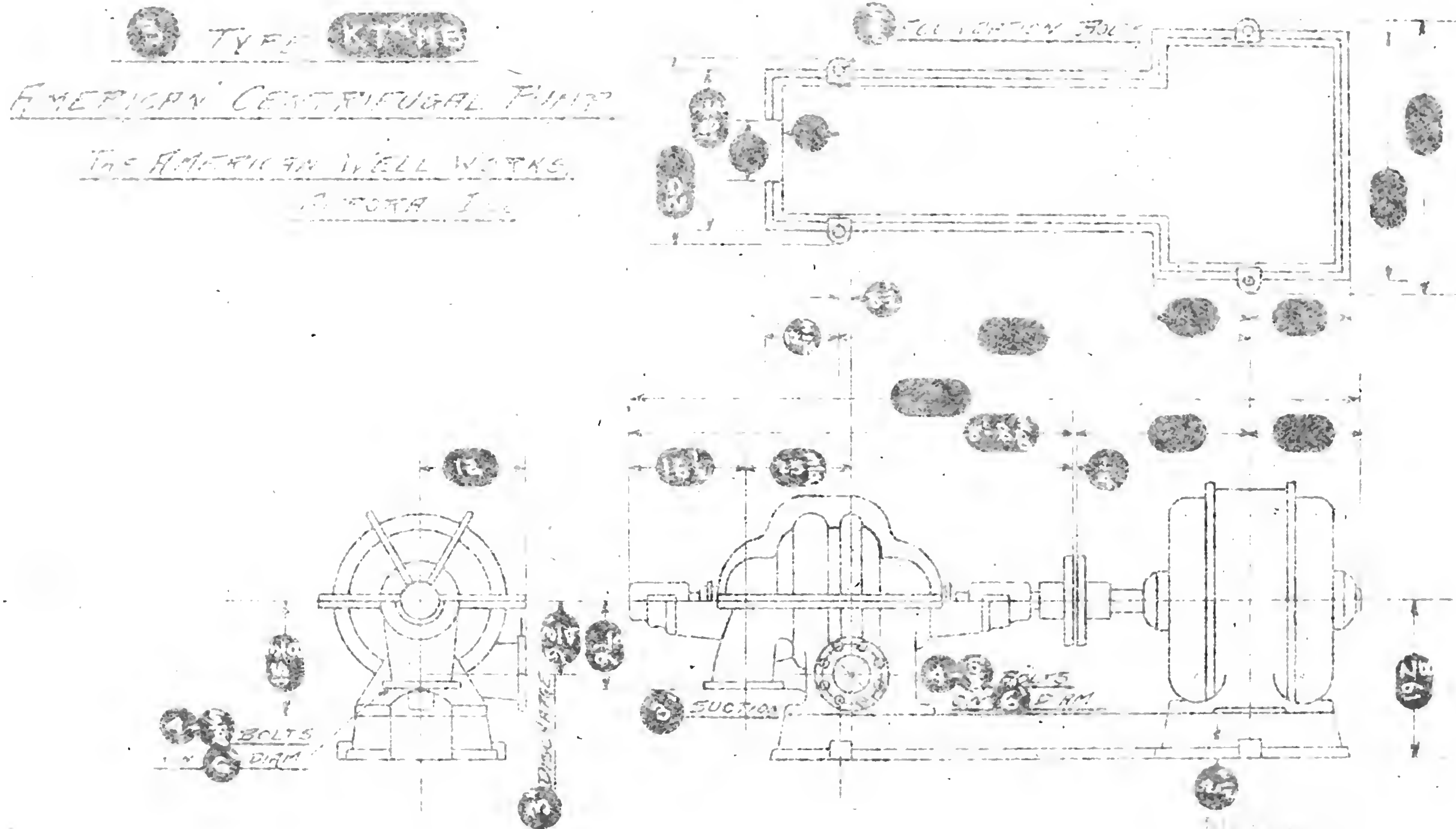


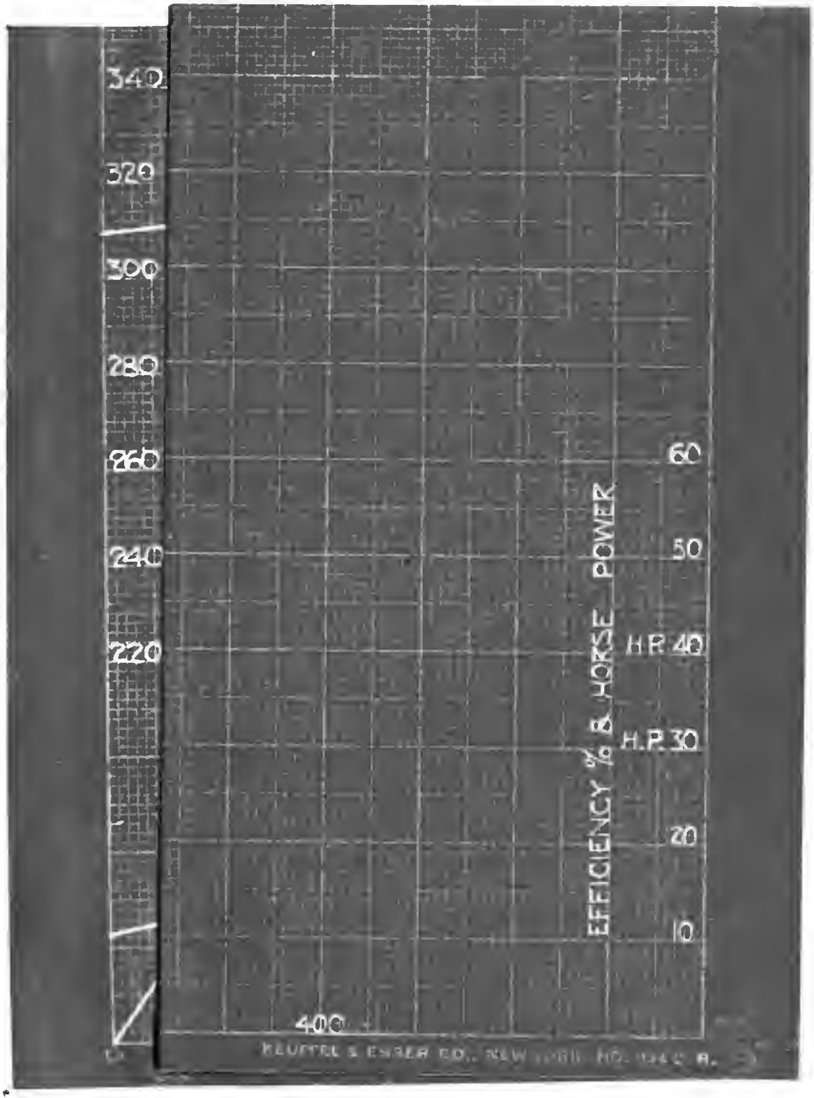


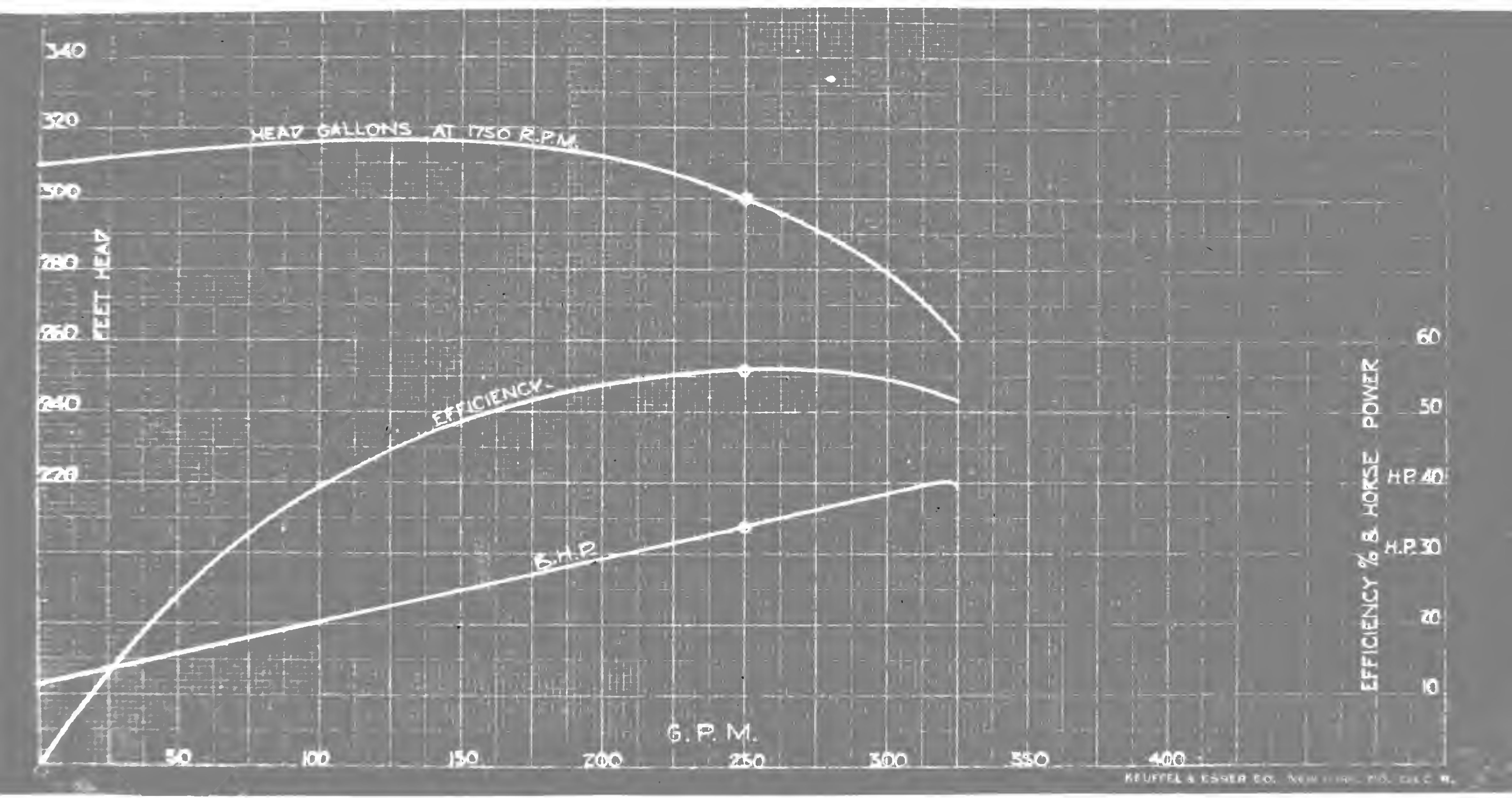

490
470
450
430
410
390
FEET HEAD
200
150
100
50
HORSE POWER
70
60
50
40
30
20
10
EFFICIENCY %
1600
KEUFFEL & ESSER CO. NEW YORK.



HEAD GALLONS AT 1750 R.P.M.
EFFICIENCY
B.H.P.
FEET HEAD
G.P.M.
HORSE POWER
EFFICIENCY %
490
470
450
430
410
390
200
400
600
800
1000
1200
1400
1600
70
60
50
40
30
20
10
200
150
100
50

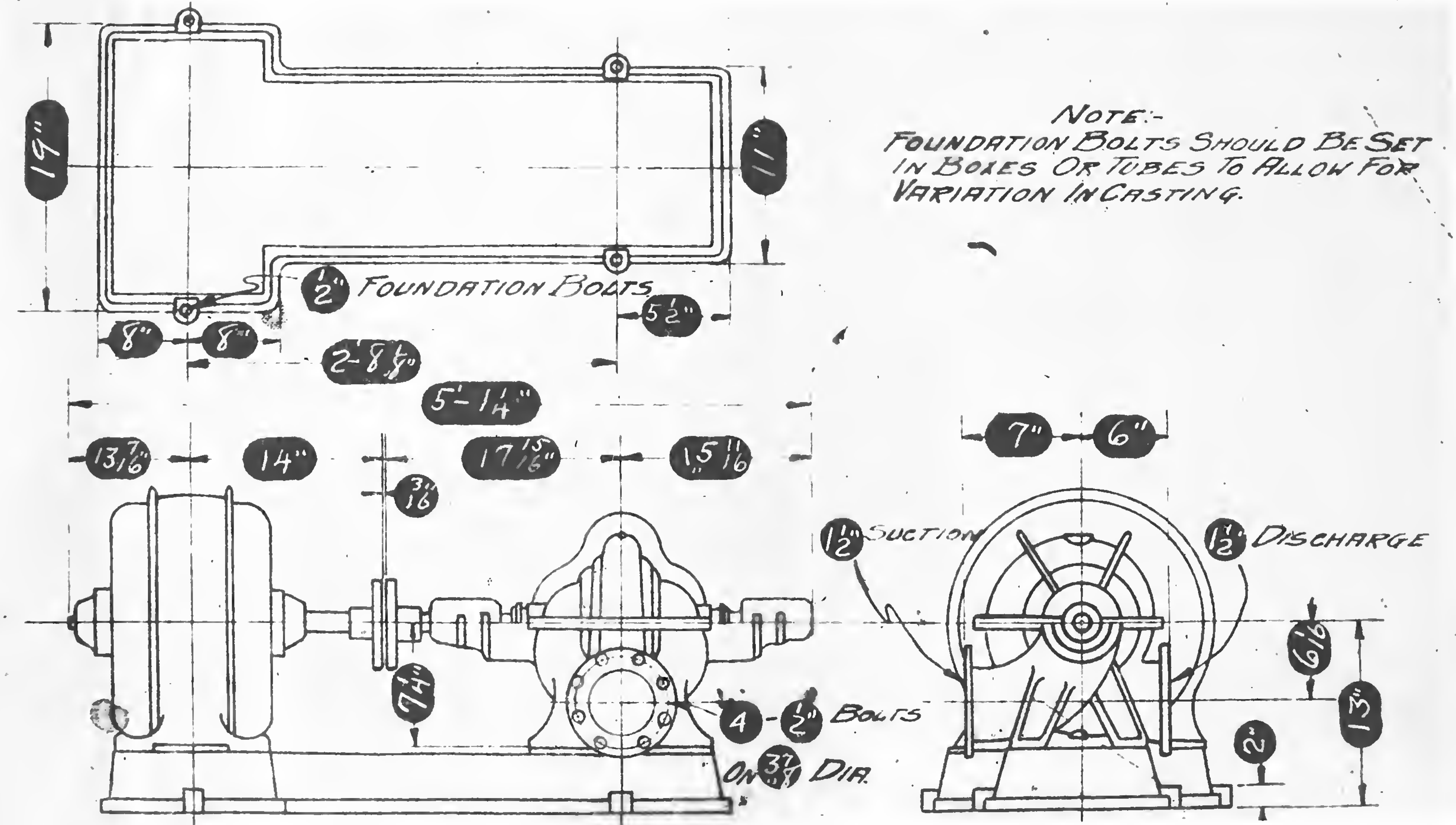

TYPE
AMERICAN CENTRIFUGAL PUMP
THE AMERICAN WELL WORKS
AURORA ILL.
BOLTS
DIAM
SUCTION
DISCHARGE


340
320
300
280
260
240
220
EFFICIENCY % & HORSE POWER
60
50
H.P 40
H.P 30
20
10
400

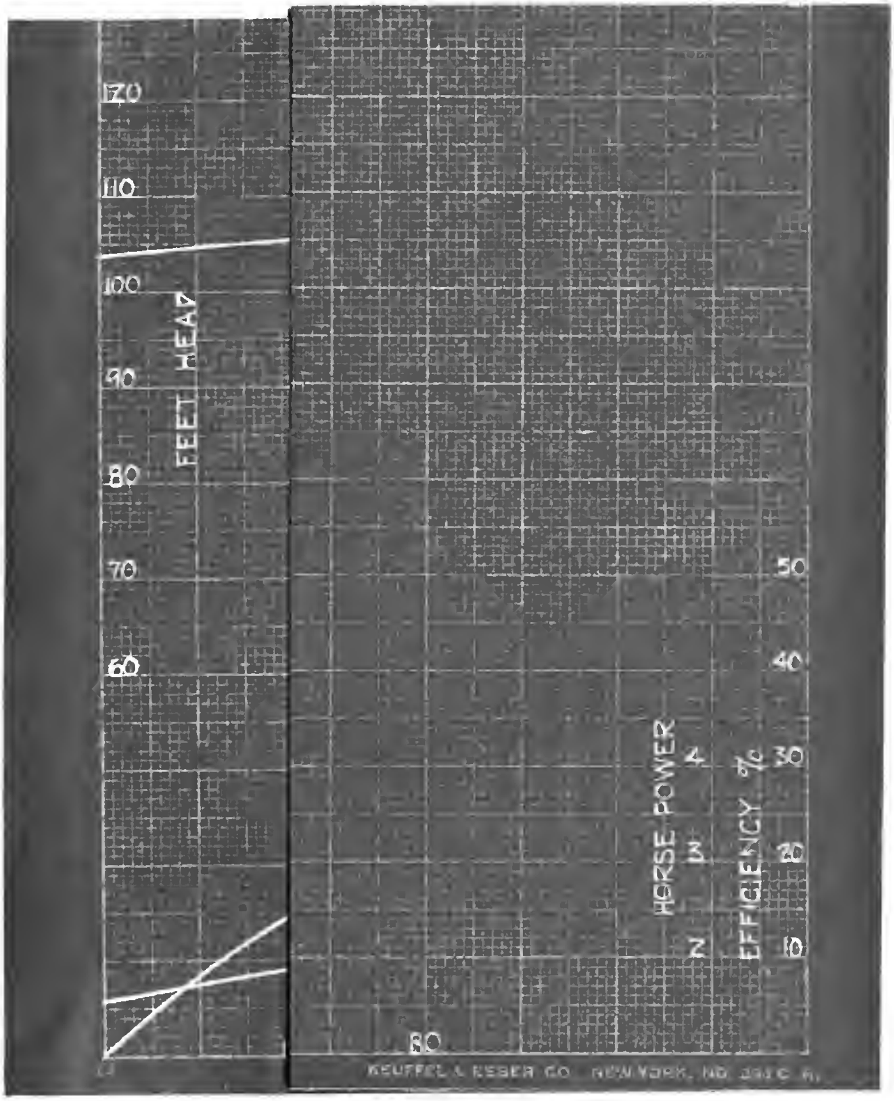


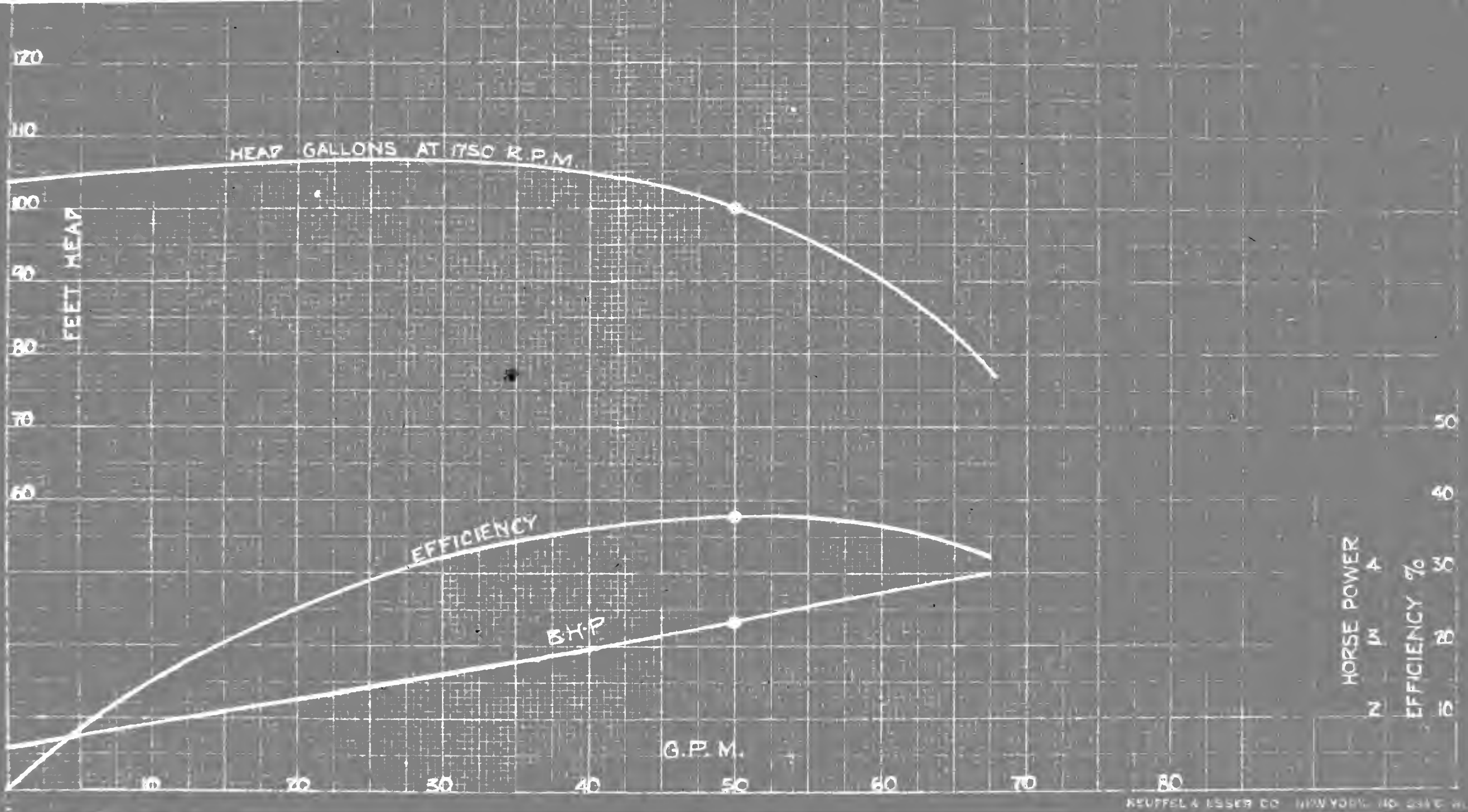
HEAD GALLONS AT 1750 R.P.M.
EFFICIENCY
B.H.P.
FEET HEAD
EFFICIENCY % & HORSE POWER
G. P. M.
340
320
300
280
260
240
220
60
50
H.P. 40
H.P. 30
20
10
50
100
150
200
250
300
350
400
KEUFFEL & ESSER CO.


19"

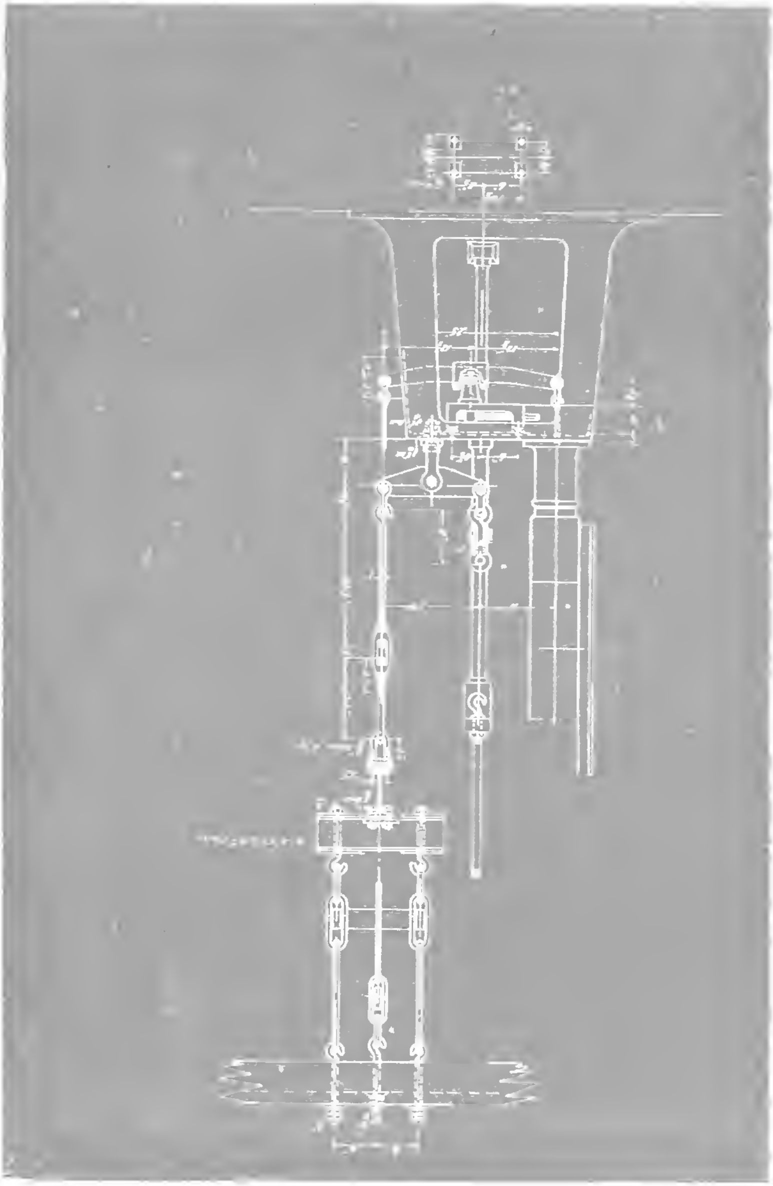


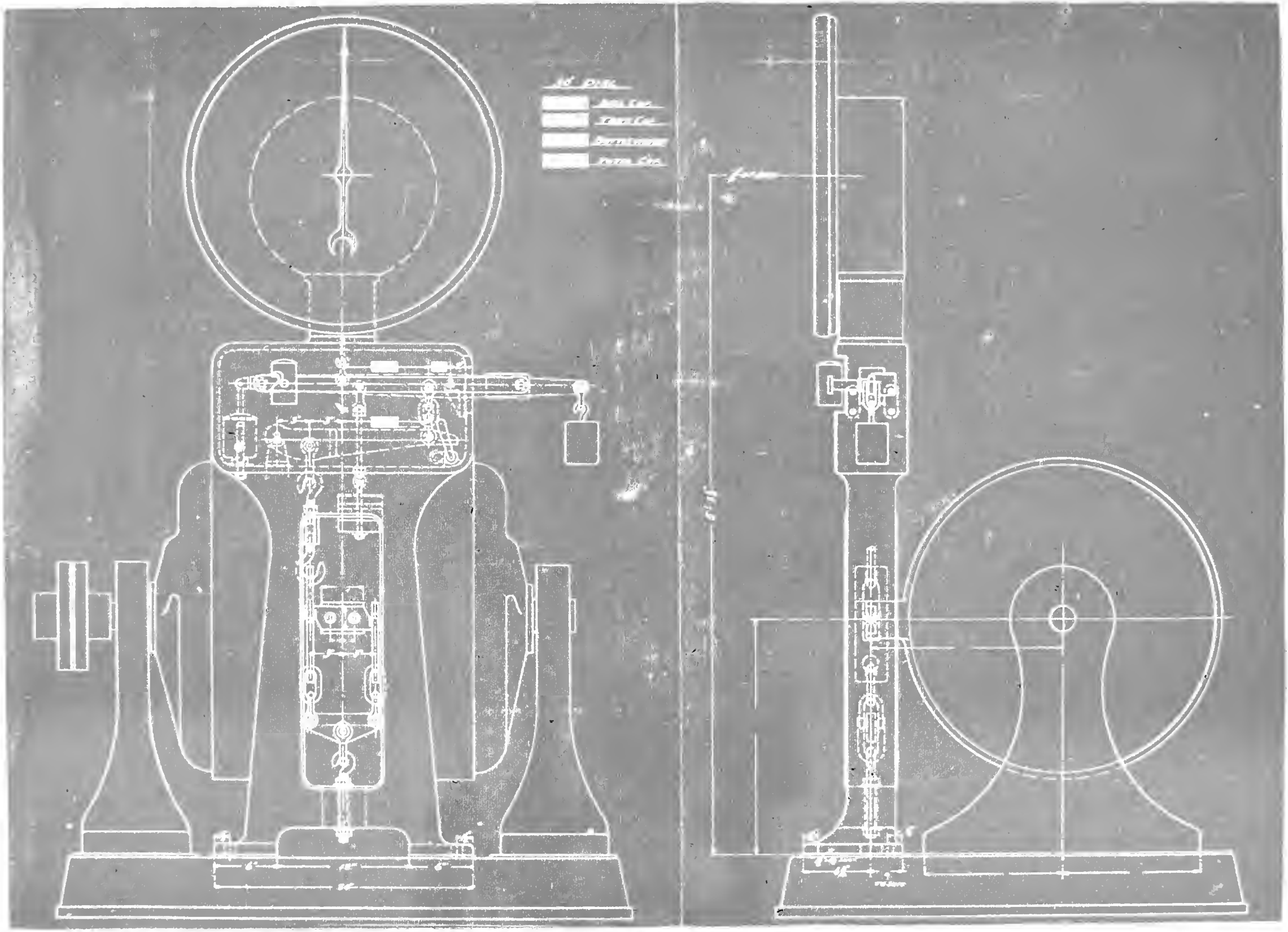
NOTE:-
FOUNDATION BOLTS SHOULD BE SET IN BOXES OR TUBES TO ALLOW FOR VARIATION IN CASTING.
19"
11"
1/2" FOUNDATION BOLTS
5 1/2"
8"
8"
2'-8 1/8"
5'-1 1/4"
13 7/16"
14"
17 15/16"
15 11/16"
3/16"
7 1/4"
4 - 1/2" BOLTS
ON 3 7/8" DIA.
7"
6"
1 1/2" SUCTION
1 1/2" DISCHARGE
6 1/16"
13"
2"

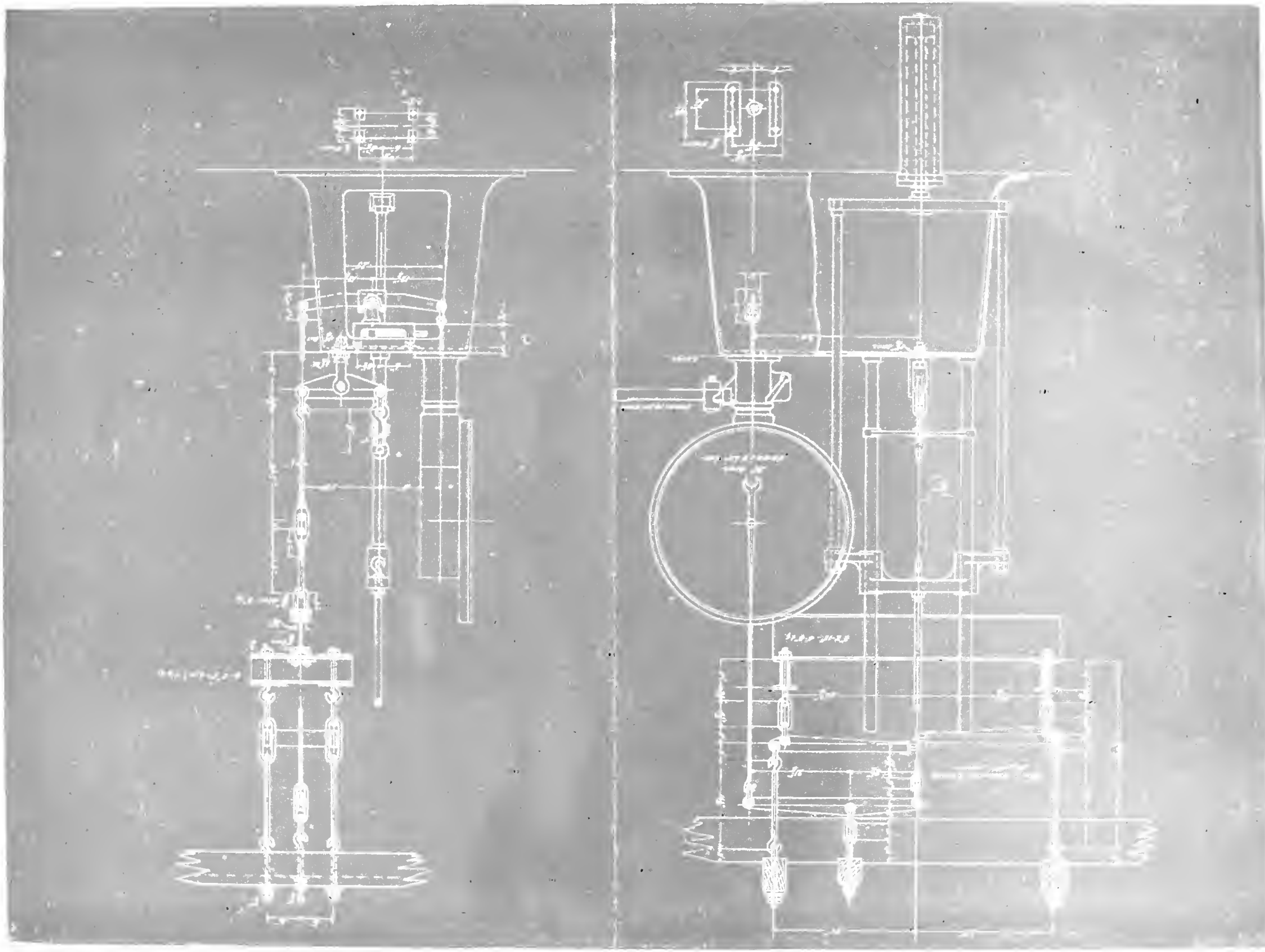

FEET HEAD
HORSE POWER
EFFICIENCY %
KEUFFEL & ESSER CO. NEW YORK



HEAD GALLONS AT 1750 R.P.M.
FEET HEAD
EFFICIENCY
B.H.P.
G.P.M.
HORSE POWER
EFFICIENCY %
120
110
100
90
80
70
60
10
20
30
40
50
60
70
80
50
40
30
20
10
4
3
2
KEUFFEL & ESSER CO. NEW YORK





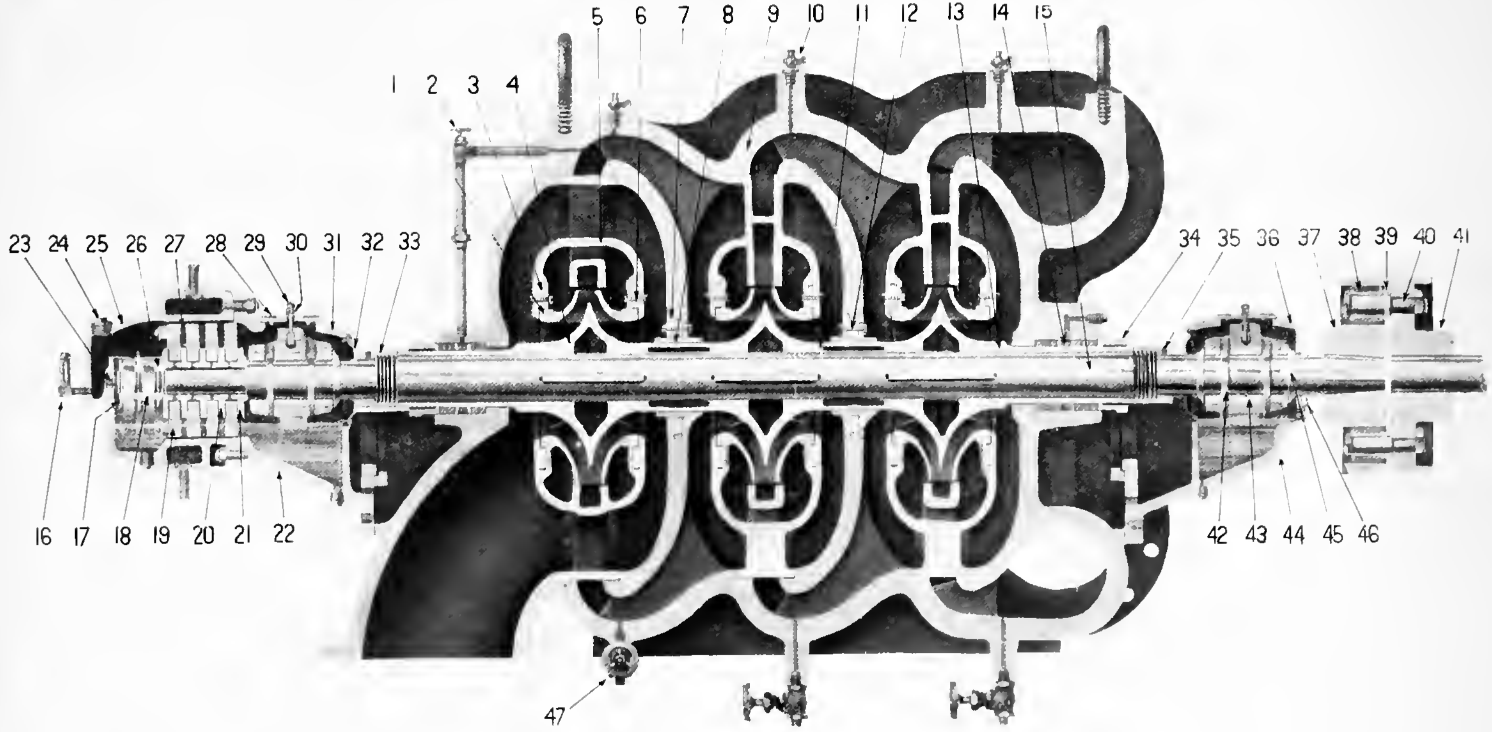


3. - 50 G.P.M.

The small centrifugal pump has a capacity of 50 gallons per minute when operating at a head of 150 feet. This pump requires three Brake H.P. when running at 1500 R.P.M. At this speed the efficiency is 43.5%.

The 350 G.P.M. and 50 G.P.M. Pumps are to be driven by electric dynamometers. The preceeding illustration shows an electric dynamometer equipped with a Kron Scale.

The specifications for these latter two pumps are the same as the preceeding one.

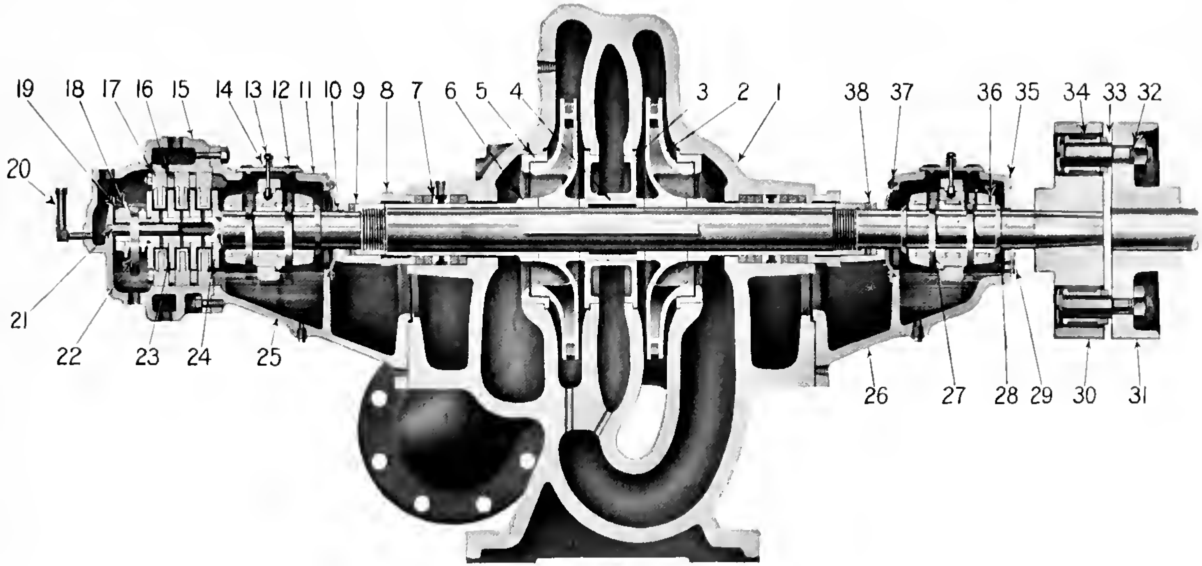


Sectional View of Jeanesville Double Suction Turbine Pump

5-Inch to 10-Inch Sizes

No.	List of Parts	No.	List of Parts	No.	List of Parts
1.	Impeller Floating Ring.	17.	Thrust Nut No. 2	33.	Shaft Nut.
2.	Water Seal Spring	18.	Thrust Nut Oil Ring	34.	Gland.
3.	Diffusion Guide Ring	19.	Thrust Block	35.	Headless Set Screw for Shaft Nut.
4.	Impeller.	20.	Thrust Collar No. 2	36.	Inboard Bearing Cap
5.	Diffusion Ring.	21.	Thrust Collar No. 1.	37.	Coupling (Pump Half)
6.	Impeller Floating Ring Screw.	22.	Outside Bearing Body.	38.	Coupling Buffer
7.	Stage Piece.	23.	Oil Pipe.	39.	Coupling Collar
8.	Stage Piece Bushing.	24.	Pipe Plug.	40.	Coupling Bolt
9.	Casing.	25.	Thrust Bearing Housing	41.	Coupling (Motor Half)
10.	Air Cock.	26.	Thrust Nut No. 1	42.	Oil Ring
11.	Distance Bushing.	27.	Distance Washer	43.	Bearing Bushing
12.	Stage Piece Bushing Screw	28.	Oil Hole Cover.	*44.	Inboard Bearing Body
13.	Shaft Sleeve.	29.	Special Dowel Pin and Nut	45.	Oil Thrower Ring
14.	Water Seal Cage.	30.	Spring for Oil Hole Cover.	46.	Shaft Pointer
15.	Shaft.	31.	Outboard Bearing Cup.	47.	Drain Cock.
16.	Oil Gauge.	32.	Inside End Cover.		

*10-inch pump has a pedestal type bearing on inboard end. All other sizes have bracket bearings as shown on cut.



Sectional View of 4 to 8-Inch S. D. Volute Pump

No.	List of Parts	No.	List of Parts	No.	List of Parts
1.	Casing.	14.	Spring for Oil Hole Cover.	27.	Oil Ring.
2.	Impeller.	15	Housing.	28.	Oil Thrower Ring.
3.	Stage Piece.	16.	Distance Washer.	29.	Shaft Pointer.
4.	Distance Bushing.	17.	Thrust Block.	30.	Coupling (pump half).
5.	Impeller Guide Ring.	18.	Thrust Nut.	31.	Coupling (motor half).
6.	Shaft Sleeve.	19.	Thrust Lock Nut.	32.	Coupling Bolt.
7.	Water Seal Cage.	20.	$\frac{1}{8}$" Oil Gauge.	33.	Coupling Collar.
8.	Gland.	21.	Oil Pipe.	34.	Coupling Buffer.
9.	Shaft Nut.	22.	Thrust Nut Oil Ring.	35.	Inboard Bearing Cap.
10.	Shaft.	23.	Thrust Bushing.	36.	Bearing Bushing.
11.	Outboard Bearing Cap.	24.	Thrust Collar.	37.	Inside End Cover.
12.	Oil Hole Cover.	25.	Outboard Bearing Body.	38.	$\frac{3}{8}$" Safety Set Screw.
13.	Special Dowel Pin and Nut.	26.	Inboard Bearing Body.		

B - STEAM RECIPROCATING PUMPS.

There are two types of steam pumps located on the main floor besides a high pressure pump.

The high pressure pump is capable of maintaining a pressure of 14,000 pounds per square inch on a steam pressure of 100#/sq.in., since the ratio of the cylinder diameter is 12 to 1. Then, since the pressure varies as the square in the diameter, and allowing 100#/sq.in. steam pressure, gives 14,400 #/sq.in. neglecting friction.

The other two pumps are for student experimental work exclusively, and consist of a single and duplex standard boiler feed pumps. To facilitate comparison of performances, pumps of the same capacity and pressure were chosen. A weir box is located between the pumps for measuring the discharge water. The weir notch in this case can be calibrated by means of the other weir.

****** SPECIFICATIONS ******

IN GENERAL.

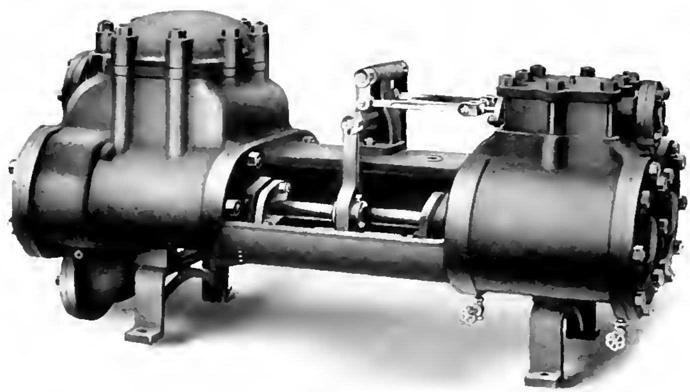
In general, the pump will be of the horizontal, single direct acting type, equipped with Simplex Valve Gear, and pump end of the double-acting piston type.

STEAM END.

The steam end will be made of close-grained cast iron, of ample thickness to allow reboring. The valve gear will be of the Simplex type without outside adjustment, which can be made while the pump is in operation. All parts will be made for hard and continuous service.

STEAM PISTON AND ROD.

The steam piston will be made of cast iron, fitted with carefully finished, self-adjusting, cast iron packing rings. The piston rod will be made of bronze, and secured to the piston by means of paper shanks and nuts. It will be made in one piece of sufficient size tO safely transmit the load.



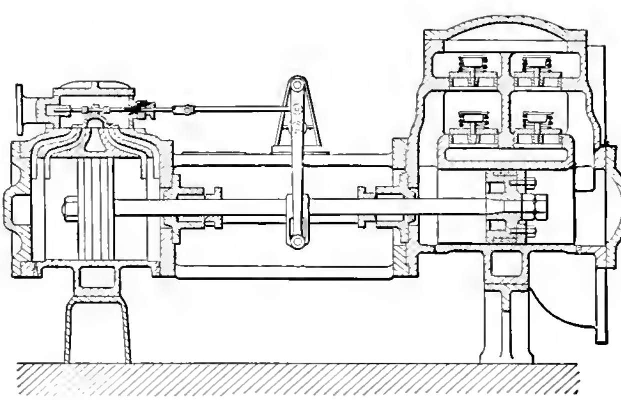


Fig. 43 Standard Submerged Piston Pattern

WATER END.

The water end will be of the cap and valve plate type made of close-grained cast iron. The piston working barrel will be fitted with a brass lining extending between ports. The port areas will be ample, and the passages short and direct. The valves and interior parts will be easily accessible by the removal of the cap and discharge valve plates.

PUMP VALVES.

The pump valves will be of the regular bronze poppet type. They will work on bronze stems and will be held on their seats by coiled brass springs. The valve seats will be of bronze, forced into the valve deck on a smooth taper, and securely held by the expahsion of the lower edge below the deck.

WATER PISTON.

The water piston will be made of cast iron, the piston to have a removable follower for convenience in getting at the packing for

adjustment or renewal without taking the piston out of the cylinder, or removing it from the rod.

RAM.

The ram, or discharge air chamber, will be of cast iron, of ample size and located on the pump cap.

C - HYDRAULIC RAM.

The equipment for the ram experiment is to consist of a supply tank located on the balcony at the necessary height. The supply line will be a two inch pipe line inclined, one foot in ten feet. Allowing for a 100 foot line, the height of the supply tank will, therefore, be ten feet above the ram. This ram will be three feet in diameter and five feet high equipped with an overflow. The water will be supplied by the City line. The ram itself will be located on the main floor. Two small weight tanks, one and one-half feet in diameter and two feet high mounted on small scales, together with the

necessary pressure gauges will complete the equipment.

****** APPARATUS FOR UTILIZING HYDRAULIC ENERGY ******

A - PELTON WHEEL.

The Pelton wheel is to be equipped with a standard calibrated nozzle. This will form a means of determining the amount of water supplied, and can be checked by the venturi meter placed in the pipe line. The Pelton wheel takes its supply from the 250 gallon per minute pump. The rest of the equipment consists of a drum and Prony brake, and scale.

B - TURBINE.

It was necessary to install a large stand pipe or penstock. This is ten feet in diameter and fifty feet high. The use of this large stand-pipe as a penstock will facilitate the handling of reaction turbines of both the inward and outward flow types.

Two small turbines are located on the main floor and are ten horsepower each. The discharge water is to flow into the flume over a weir notch, to be measured, before flowing into the sump.

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